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COMMUNITY NOISE

DECEMBER 31, 1971

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COMMUNITY NOISE

DECEMBER 31, 1971

Prepared by

WYLE LABORATORIES
under
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for the

U.S. Environmental Protection Agency
Office of Noise Abatement and Control
Washington, D.C. 20460

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1.0 INTRODUCTION

A person's acoustical environment consists of the sound that he hears at any instant of time. The sound may be pleasant and desirable, or it may be discordant and unwanted. In the latter case, the sound is called "noise", which is defined simply as "unwanted sound".

If a noise is sufficiently loud, it may intefere with one's ability to converse with another person, disturb sleep, add to the risk of hearing damage, or otherwise annoy the listener. A noise which adversely affects people in this manner can be considered to pollute the acoustical environment. Thus, noise pollution is the contamination of the acoustical environment by noises which adversely affect people.

A person indoors may experience noise pollution from sources located indoors, such as a vacuum cleaner, air conditioner, or someone else's radio. Or, he may experience noise pollution which enters the house through a closed or partially opened window from sources located outdoors, such as motorcycles, aircraft, and power lawnmowers. A person outdoors is also subject to noise pollution from outdoor sources, in addition to nearby indoor sources such as a loud radio in a room with open windows.

All aspects of noise pollution, with the exception of occupational noise, together with a description of the noise characteristics and potential noise control for all principal noise sources, and a review of the legal status of noise pollution are contained in the Environmental Protection Agency Report[1*] to Congress.

This report addresses the part of the overall noise pollution problem which is associated with outdoor noise in the community. It attempts to provide a quantitative framework for understanding the nature of the outdoor noise environment and the reaction of people and community to its various aspects. The detailed information in this report provides backup to the summary material in the EPA report, as well as additional material relevant to meaningful measures of the noise environment for both future community noise monitoring and research purposes.

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* Superscripts refer to references at the end of this report.

Chapter 2 contains an introduction to the basic measures of the noise environment and the manner with which they vary throughout a 24-hour day at a single location. Chapter 3 presents the general results of 24-hour noise surveys at 18 locations, which ranged from the wilderness to the downtown city. The locations were deliberately chosen to encompass the range of outdoor noise environments which affect citizens in their daily life, outside of work. The data also provide a test of the relationship among various measures of noise for a wide variety of noise environments.

Chapter 4 discusses the nature of some of the constant and intermittent intruding sounds which are common in our society, and the constraints that these intruding noises place on speech communication and other human activities. Chapter 5 discusses annoyance and community reaction to noise, developing a useful correlation between physical measures of an intruding noise, related factors, and community reaction. Chapter 6 discusses the growth of noise pollution over the past two decades, and Chapter 7 contains summary conclusions and recommendations.

Appendix A gives a detailed summary of the data obtained at the 18 locations surveyed. Appendix B gives typical examples of the spectra of the intruding noises and Appendix C contains a glossary of terms.

2.0 DESCRIPTION OF THE OUTDOOR NOISE ENVIRONMENT

The description of community noise and its degree of noise pollution requires description of all the noises in the outdoor acoustical environment. The outdoor noise environment varies greatly in magnitude and character among various locations throughout a community – from the quiet suburban areas bordering on farm land to the din of traffic in the downtown city canyon. It generally varies with time of day in each location, being relatively quiet at night when people-activities are at a minimum and noisier in the late afternoon during the 5 o'clock traffic rush. Its effects may be experienced by people either in or out of doors. Thus, the task of describing community noise is to determine the time and location variations in the outdoor noise environment throughout the community in such a manner that the descriptions are relevant to its effects on people, located either indoors or outdoors. This chapter reviews the basic and statistical descriptions of the time variation of the outdoor environment at a specific location, and Chapter 3 reviews the general range of the expected variation with location.

2.1 Basic Physical Description

A complete physical description of a sound must account for its frequency spectrum, its overall sound pressure level, and the variation of both of these quantities with time. Because it is awkward to present and understand data which have three dimensions, considerable effort has been expended during the last 50 years to develop scales which reduce the number of these dimensions.[2]

Most of the effort has been focused on combining measures of the frequency content and overall level into a quantity proportional to the magnitude of the sound as heard by a person. The simplest approach found to date is to electronically weight the amplitudes of the various frequencies approximately in accordance with a person's hearing sensitivity and sum the resulting weighted spectrum to obtain a single number. This method is illustrated in Figure 1 for the A-weighting contained in a sound level meter.[3] The A-weighting has been available in sound level meters since the late 1930's and has been utilized extensively for measurement of all types of sounds.

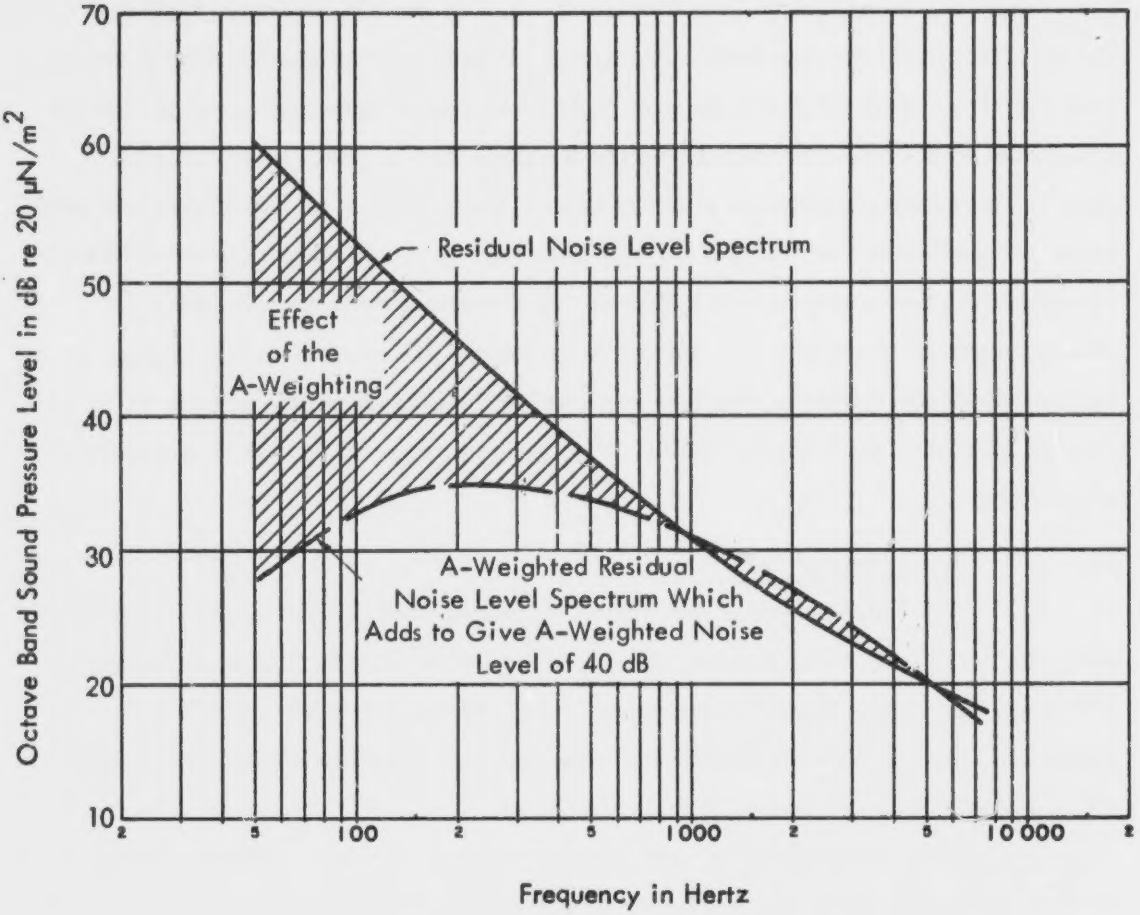


Figure 1. A Typical Octave Band Spectrum of the Outdoor Residual Noise Level in Late Evening in a Normal Suburban Neighborhood Illustrating the Effect of the A-Weighting on the Relative Importance of Various Frequency Bands

Because the A-weighting is not a perfect solution for the accounting of man's perception of the frequency characteristics of a sound, many other scales have been developed which attempt to better quantify "loudness" and/or "noisiness."[4-9] One of these, the tone-corrected perceived noise level,[9] better accounts for the ear's frequency response function, and also has the ability to differentiate between noises which are broadband random (roar) in nature and those which contain high frequency pure tones (siren), penalizing the latter. For most sounds, the perceived noise level exceeds the A-weighted noise level by 13 dB, the differences typically ranging between 11 and 17 dB, depending primarily upon the amount of the correction for pure tones.[9,10,11] Because the perceived noise level scale is somewhat more exact than the A-weighting in relating the physical characteristics of a sound to perceived noisiness, particularly for aircraft noises, it has become a major element in the noise scale used for certifying aircraft.[12,13]

The tone-corrected perceived noise level scale and the better loudness summations require complex measurement instrumentation and data analysis to define a sound. Therefore, they have found little application in the measurement of outdoor noise in the community, where the simple A-weighted sound level meter appears to serve the purpose quite adequately. Accordingly, the A-weighting is the principal measure of the magnitude of sound used in this report, accounting for both spectrum and overall level.

To complete the description of the outdoor noise environment at a specific location, it is necessary to account for the temporal pattern of the A-weighted noise level. The temporal pattern is most easily observed on a continuous graphic level recording, such as the two 8-minute samples illustrated in Figure 2.

The first striking feature of these two samples is that the noise level varies with time over a range of 33 dB, which is greater than an eight-fold range of noisiness.

The second major feature of the samples is that the noise appears to be characterized by a fairly steady lower level upon which is superimposed the increased levels associated with discrete single events. This fairly constant lower level is called

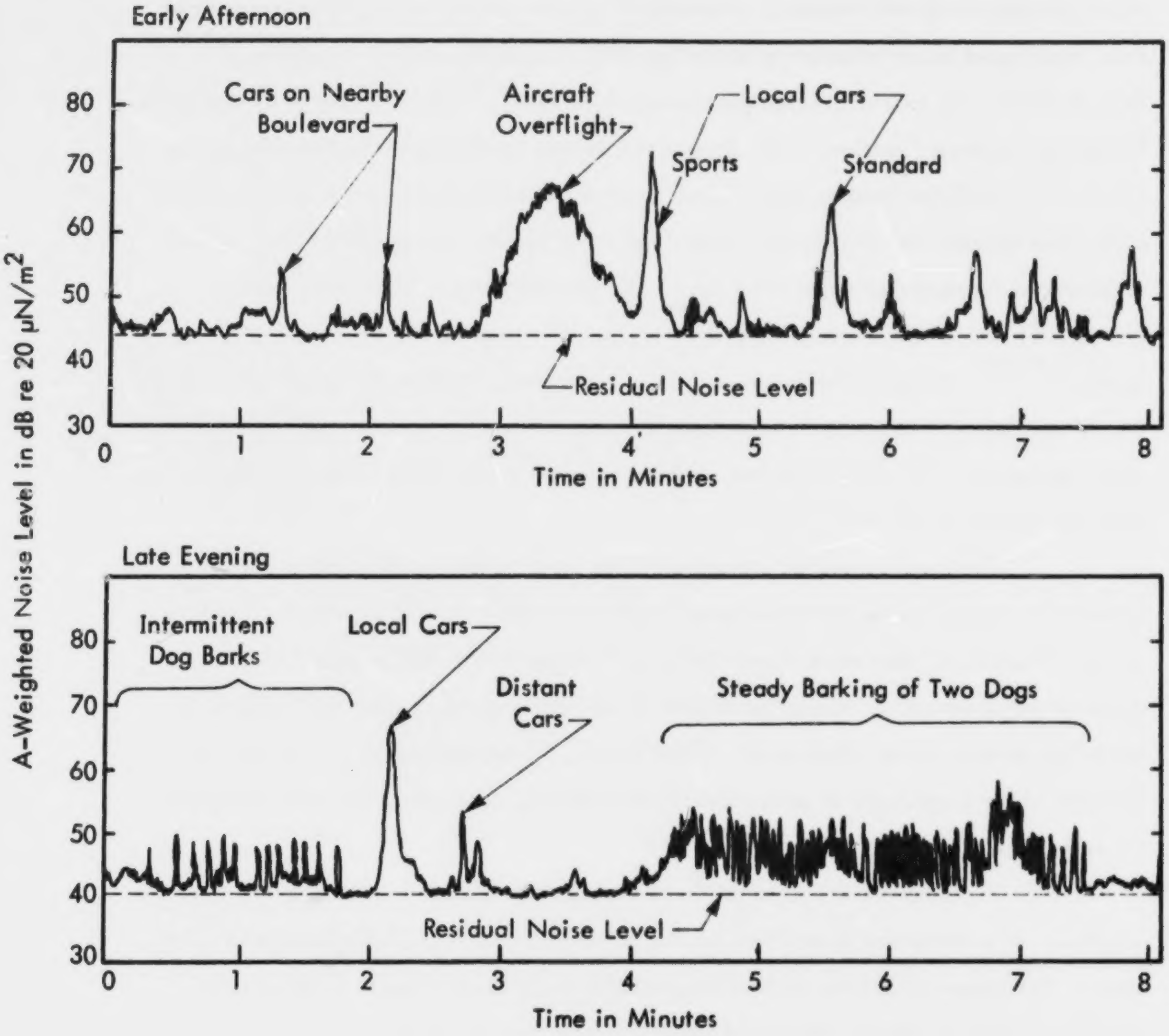


Figure 2. Two Samples of Outdoor Noise in a Normal Suburban Neighborhood with the Microphone Located 20 Feet from the Street Curb

the residual noise level. The continuous noise one hears in the backyard at night when no single source can be identified, and which seems to come from "all around," is an example of residual noise. Distinct sounds which are superimposed on the residual noise level, such as the aircraft overflight, cars, and dogs barking (Figure 2) can be classified as intrusive noises.

The third feature in these two samples is the difference in the noise level – time patterns among the various sounds. The noise level of the aircraft in this example is above that of the residual noise level for approximately 80 seconds, whereas the noise levels from the cars passing by on the street are above the residual noise level for much shorter durations which range between about 5 and 20 seconds. Clearly, if the noise associated with these single events were of sufficient magnitude to intrude on an individual's activities – conversation, thinking, watching television, et cetera – the duration factor might be expected to affect his degree of annoyance. Similarly, it might be anticipated that the number of times such an event recurred also would affect his degree of annoyance.

The wealth of detailed data contained in continuous recordings of this type is further illustrated in Figure 3 by the half-hour samples taken at the beginning of each hour from Midnight to 10:00 a.m. This example shows both the short time variations associated with single event noises and the longer time changes in the level, as well as in the characteristics of the temporal patterns. The residual noise level decreases from approximately 40 dB(A) at Midnight to 30 dB(A) between 4:00 a.m. and 6:00 a.m., and then increases to about 42 dB(A) at 10:00 a.m. Aircraft noise is generally absent between Midnight and 7:00 a.m., after which it becomes the dominant intrusive noise. Local vehicle traffic is generally less frequent in the 1:00 a.m. to 7:00 a.m. period, after the teenagers have returned home for the night and prior to the adults starting to drive to work.

The data from these continuous noise recordings is very instructive in understanding the nature of the outdoor noise environment at any neighborhood location. However, to quantify an outdoor noise environment at one location so that it can be

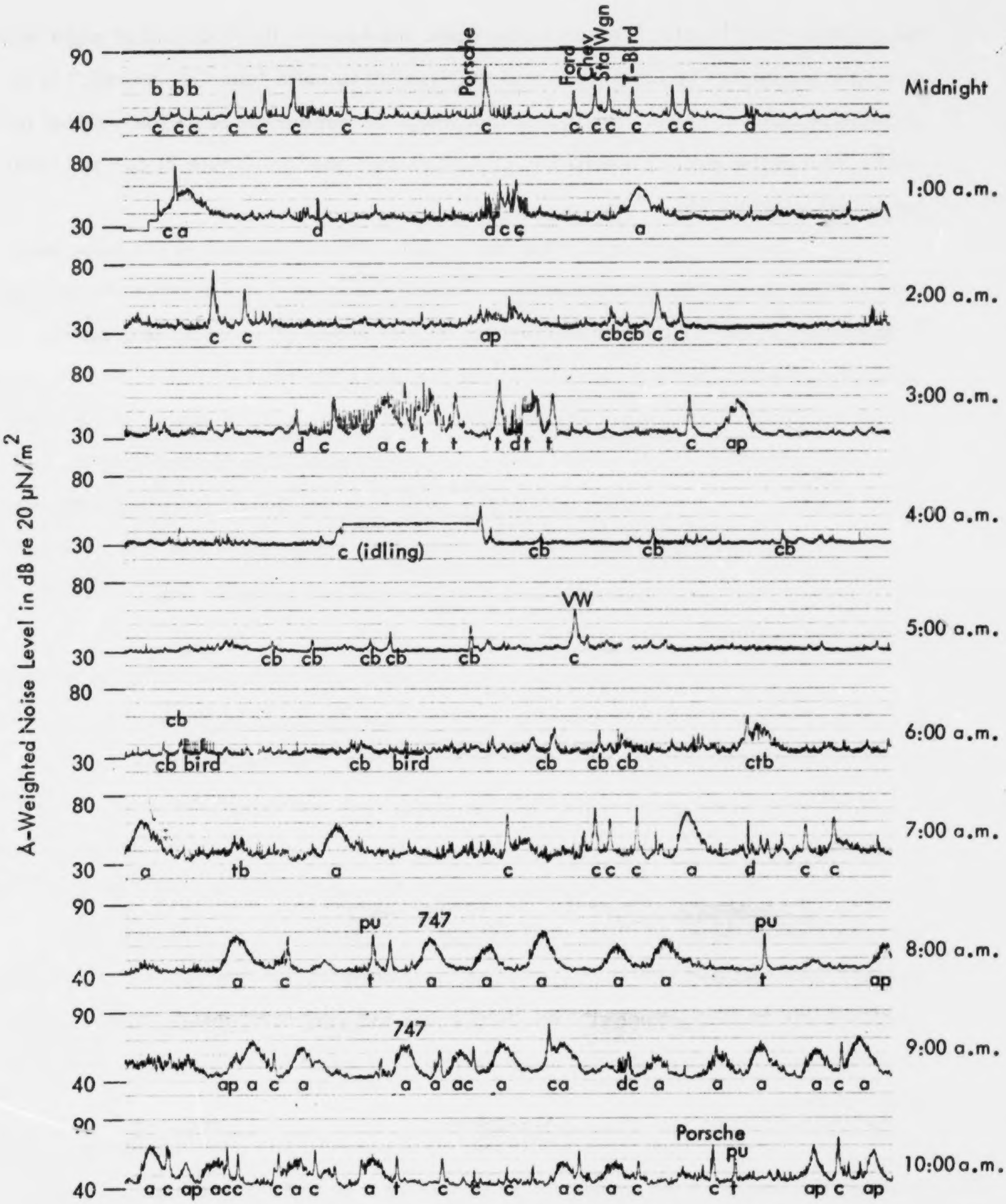


Figure 3. Example of One-Half Hour Graphic Level Recordings Beginning on Each Hour from Midnight Through 10:00 A.M. at a Residence in a Normal Suburban Neighborhood. Events Identified by the Following Letter Code: a - Jet Aircraft; ap - Propeller Aircraft; c - Automobile; cb or b/c - Automobile in Background; d - Dog; t - Truck; pu/t - Pickup Truck; tb - Truck in Background. The Symbol / Indicates the Time History Trace, with Letter Codes Above and Below It.

compared with that at others, it is necessary to simplify its description by eliminating much of the temporal detail. One way of accomplishing this simplification is to measure the value of the residual noise level and the values of the maximum noise level for specific single event sounds at various times during the day, using either a simple sound level meter or the continuous graphic level recording of its output. Another method of quantifying the noise environment is to determine the statistical properties of the noise level by attaching a statistical analyzer on the output of the sound level meter. These methods for simplifying the third dimension of the noise environment will be illustrated in the next section.

2.2 Statistical Description

A statistical analysis of the noise level gives the percentage of total time that the value of the noise level is found between any two set limits. Such data can be presented directly in the form of histograms, or be used to obtain a cumulative distribution in terms of the "level exceeded for a stated percentage of time." For the sample statistical distribution of Table 1, the noise level exceeds 60 dB(A) for 1 percent of the hour, 55 dB(A) for 10 percent of the hour, 50 dB(A) for 50 percent of the hour, and 45 dB(A) for 90 percent of the hour. These noise levels are abbreviated symbolically as L_1, L_{10}, L_{50} and L_{90}, respectively.

Table 1

Example of Statistical Distribution of Outdoor Noise Analyzed in Intervals of 5 dB Widths

Interval in dB(A)	Percent of Total Time	Cumulative Percent of Total Time
61 through 65	1	1
56 through 60	9	10
51 through 55	40	50
46 through 50	40	90
41 through 45	10	100

Histograms and cumulative distribution for the noise levels are given in Figure 4 for two hours of the data, illustrated previously in Figure 3. The histogram for the hour between 5:00 a.m. and 6:00 a.m. is almost symmetrical, indicating a gaussian or normal distribution. However, the histogram for the hour between 8:00 a.m. and 9:00 a.m. is very non-symmetrical, indicating a skewed non-gaussian distribution. This skewed distribution between 8:00 a.m. and 9:00 a.m. is the result of the large percentage of time during which noise was present from aircraft overflights.

Both the direct reading and the statistical methods have been applied to a 24-hour recording of the outdoor noise level at a suburban residential location. The variation of the hourly, and the day (7:00 a.m. - 7:00 p.m.), evening (7:00 p.m. - 10:00 p.m.) and nighttime (10:00 p.m. - 7:00 a.m.) values of various statistical measures, together with the minimum and maximum values read from a continuous recording, are summarized in Figure 5.

For purposes of this report, the level exceeded 90 percent of the time (L_{90}) was selected as an approximate measure of the residual noise level when there were no identifiable steady-state or frequent recurring single event noises present. As illustrated in Figure 5, the hourly values of L_{90} compare favorably with the hourly values of the residual noise levels read from graphic level recordings, which in turn generally compare well with the average minimum values obtained when reading a sound level meter.

The median noise level (L_{50}) is a useful measure of the "average" noise environment in the sense that one-half of the time it is quieter and one-half of the time it is noisier than L_{50}. Both L_{10} and L_1 are often used to represent the higher-level shorter-duration sounds. However, as shown in the example of Figure 5, the maximum noise levels in an hour are often much greater than the highest statistical measure (L_1) which was used in the analysis, indicating that these maximum noise levels occur for less than 1 percent of the time during the period analyzed.

The dashed line in Figure 5, labeled L_{eq}, is the energy equivalent noise level (L_{eq}) which accounts for both the duration and the magnitude of all the sounds occurring in the time period. Its value equals that of a steady-state noise which has the

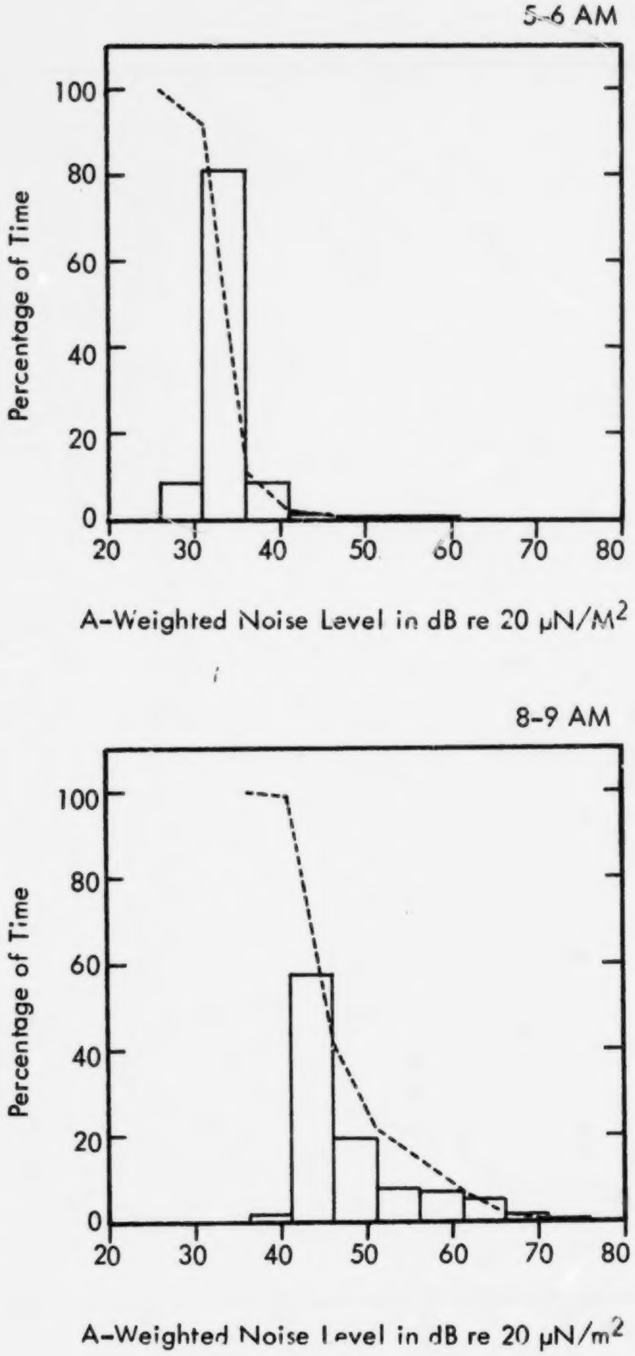


Figure 4. Histograms and Cumulative Distribution of Noise Levels for Two (2) One-Hour Periods of Data from Figure 3

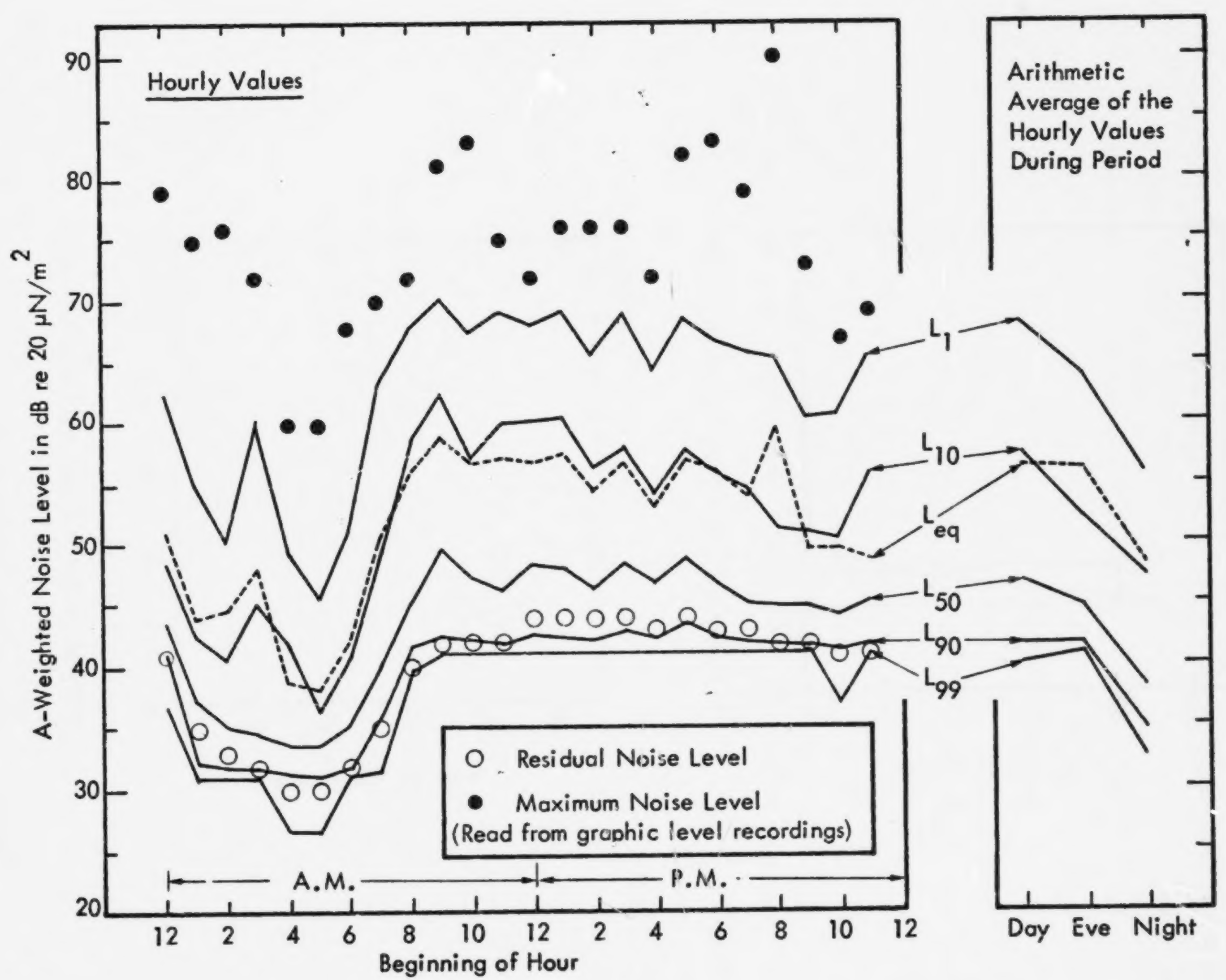


Figure 5. Statistical Portrayal of Community Noise Throughout 24 Hours at a Residence in a Normal Suburban Neighborhood. Data Include the Maximum & Residual Noise Levels Read from a Graphic Level Recorder, Together with the Hourly & Period Values of the Levels Which are Exceeded 99, 90, 50, 10 and 1 Percent of the Time, and the Energy Mean Equivalent Level (L_{eq})

same energy during the period analyzed as that of the actual time-varying noise. The energy equivalent noise level is one of the most important measures of the outdoor noise environment for the purpose of correlating noise and community reaction.

All of the statistical measures in Figure 5 show the typical daytime-nighttime variation in noise level. In this example, the residual noise level drops sharply after midnight reaching a minimum value between 4:00 a.m. and 5:00 a.m., and rises between 6:00 a.m. and 8:00 a.m. to its almost constant daytime value. This time variation of the noise is generally well correlated with the amount of human activity, and particularly with the amount of vehicular traffic, which is generally considered to be the basic source of the residual noise level in urban areas.

These statistical measures simplify the problem of quantifying the outdoor noise level and will be used in this report to compare the outdoor noise environments in various places. However, they must be supplemented by other observations if one is to understand anything of the character of the outdoor noise environment beyond the simple statistics of the noise levels. Further, they may be misleading if the character of the noise environment changes significantly within the period analyzed statistically.

The values of the statistical quantities given for the day, evening and night periods in Figure 5 represent the arithmetic average of the hourly values measured during each period. The average of the hourly values of any one of the statistical quantities during a period should be equal to the value computed directly from the ensemble of the data for the entire period if the characteristics of the noise remain constant (or stationary) during the period. However, if the characteristics change within the period, these two methods of calculation may yield different answers.

Table 2 gives the magnitude of the differences between these two calculation methods. Only small differences occurred during the day and evening periods, indicating that the noise characteristics are relatively stationary within each of these periods. However, larger differences of the order of 3 to 5 dB are found for the L_{90} and L_{10} values in the night and 24-hour periods, indicating the noise level characteristics are non-stationary. These indications are confirmed by inspection of Figure 5 which shows that the noise has a significantly lower level in the hours between 1:00 a.m. and 7:00 a.m.

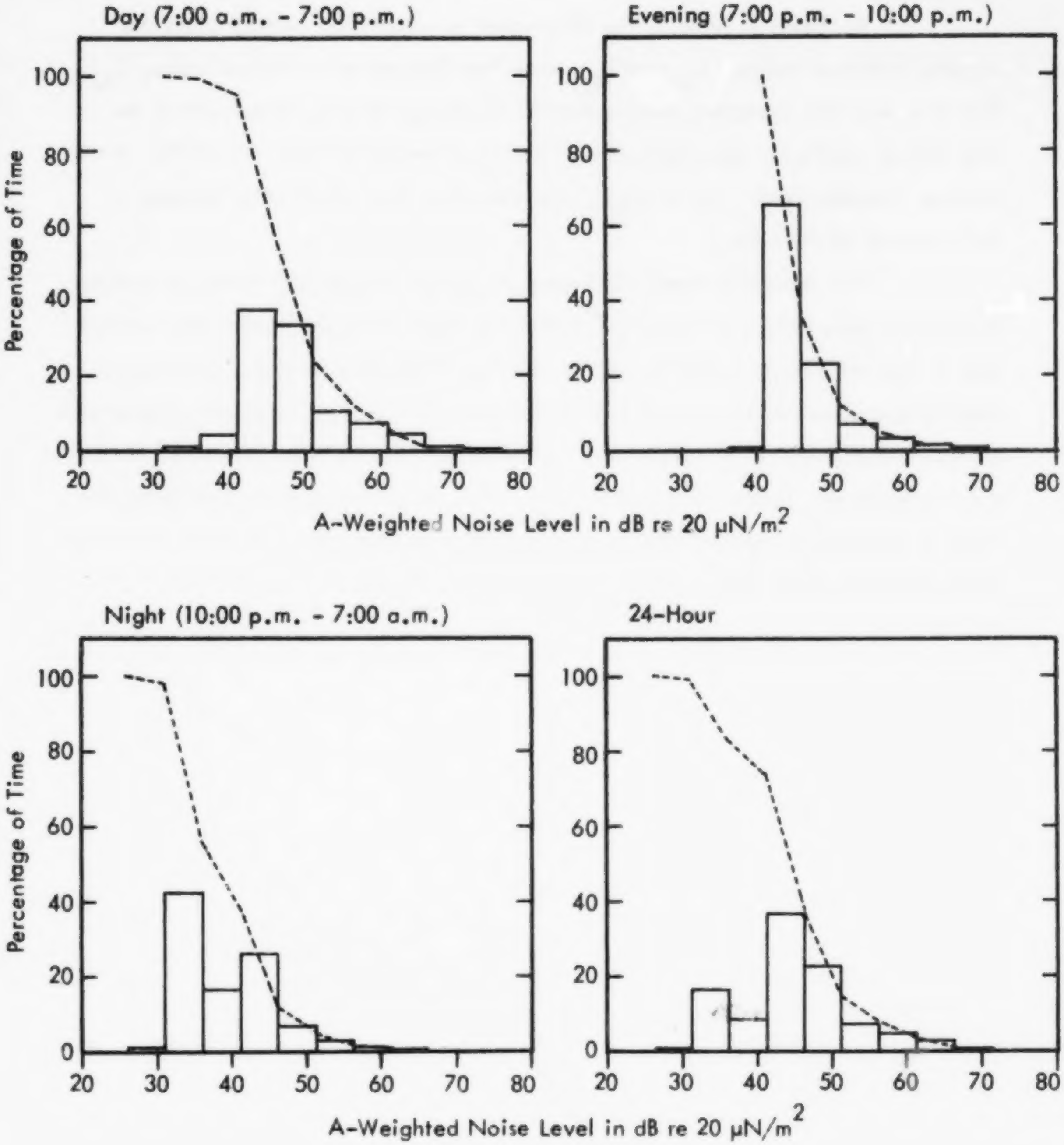
Table 2

Example of the Variation in the Statistical Measures of Outdoor Noise Level for Several Periods in a 24-Hour Day, as a Function of Calculation Technique for the Data of Figure 5

Variable		Day	Eve	Night	24-Hour
L_{90}	Hourly Mean* Period Value**	41.9 41.6	41.8 41.8	34.9 32.0	39.3 33.9
	Δ	0.3	0.0	2.9	5.4
L_{50}	Hourly Mean Period Value	46.8 47.1	44.8 44.8	38.1 37.6	43.3 44.3
	Δ	-0.3	0.0	0.5	-1.0
L_{10}	Hourly Mean Period Value	57.4 58.2	52.1 52.3	44.7 47.4	52.0 54.7
	Δ	-0.8	-0.2	-2.7	-2.7

* Hourly Mean is the arithmetic mean of the hourly values.
** Period Value is calculated from the statistical ensemble for the entire period.

A second indication of a difference in the character of the various time periods is given by their distributions in Figure 6. The bi-modal distributions for both the night and 24-hour time periods results from the many hours of relatively low values during the night. Clearly, "nighttime," as far as the quiet noise environment is concerned in this particular example, occurred between approximately 1:00 a.m. and 7:00 a.m., rather than between the arbitrary limits of 10:00 p.m. and 7:00 a.m.



Day (7:00 a.m. - 7:00 p.m.)

Evening (7:00 p.m. - 10:00 p.m.)

Night (10:00 p.m. - 7:00 a.m.)

24-Hour

Figure 6. Histogram and Cumulative Distribution of the Noise Levels of Figure 5 Throughout the Day

As shown in Table 2, the differences in calculation method affect the extreme statistical values, L_{10} and L_{90}, more than the central statistical value, L_{50}. This is as would be expected, since a significant change for only 10 percent of the time during a period is required to affect the former two quantities. Obviously, more extreme measures, such as L_1 and L_{99}, would be even more sensitive to changes in the character of the noise.

This discussion clearly indicates the danger in applying statistical analysis to non-stationary noise environments, in that the results obtained for one environment may or may not afford a valid comparison to those obtained in another environment, depending on how stationary each environment is. To minimize the problem and provide a consistant approach in this report, all period values have been calculated by averaging the hourly values, except where noted. Secondly, the principal definition of outdoor noise at various locations emphasizes the daytime noise characteristics which tend to be more stationary in character than the noise in other periods.

3.0 RANGE OF OUTDOOR NOISE ENVIRONMENTS

In order to define for this report the range of outdoor noise environments encountered by people in their normal activities, a series of 24-hour outdoor noise recordings was made at each of eighteen (18) sites. This exploratory measurement survey was planned to sample noises in all types of locations, from the wilderness to the downtown city, with major emphasis in the suburban and urban residential areas, and to include examples of some of today's more significant noise pollution problems. Thus, the survey presents a preliminary cross-section of the noise environment; but since it was not designed to be weighted by population density, it cannot give a true statistical picture of the noise environment in terms of a national baseline. This chapter describes the general results of the survey in terms of the variation of several statistical measures of the noise environment with both location and time of day, and discusses the interrelationships among some of these measures. A detailed summary of the measurement sites and data together with the survey instrumentation are given in Appendix A.

3.1 Variation of Outdoor Noise Environment with Location

The range of daytime outdoor noise levels at the 18 locations is presented in Figure 7. The locations are listed from top to bottom of the figure in descending order of their daytime residual noise levels (L_{90}). The noisiest location, which is outside of a 3rd floor apartment overlooking an 8-lane freeway, is at the top of the list with its daytime residual noise level of 77 dB(A). The rural farm is next to the bottom of the list with its daytime residual noise level of 33 dB(A).

This difference of 44 dB in the residual noise levels of these two locations constitutes a large range in noise climate. Its magnitude clearly implies that all citizens do not enjoy the same "quality" in their noise environment. In fact, the owner of the 3rd floor apartment near the freeway has trouble keeping the apartment rented for more than a month to any one tenant. His problem is not surprising, since the outdoor noise level is sufficiently high to render normal speech communication difficult indoors, even when the windows are closed.

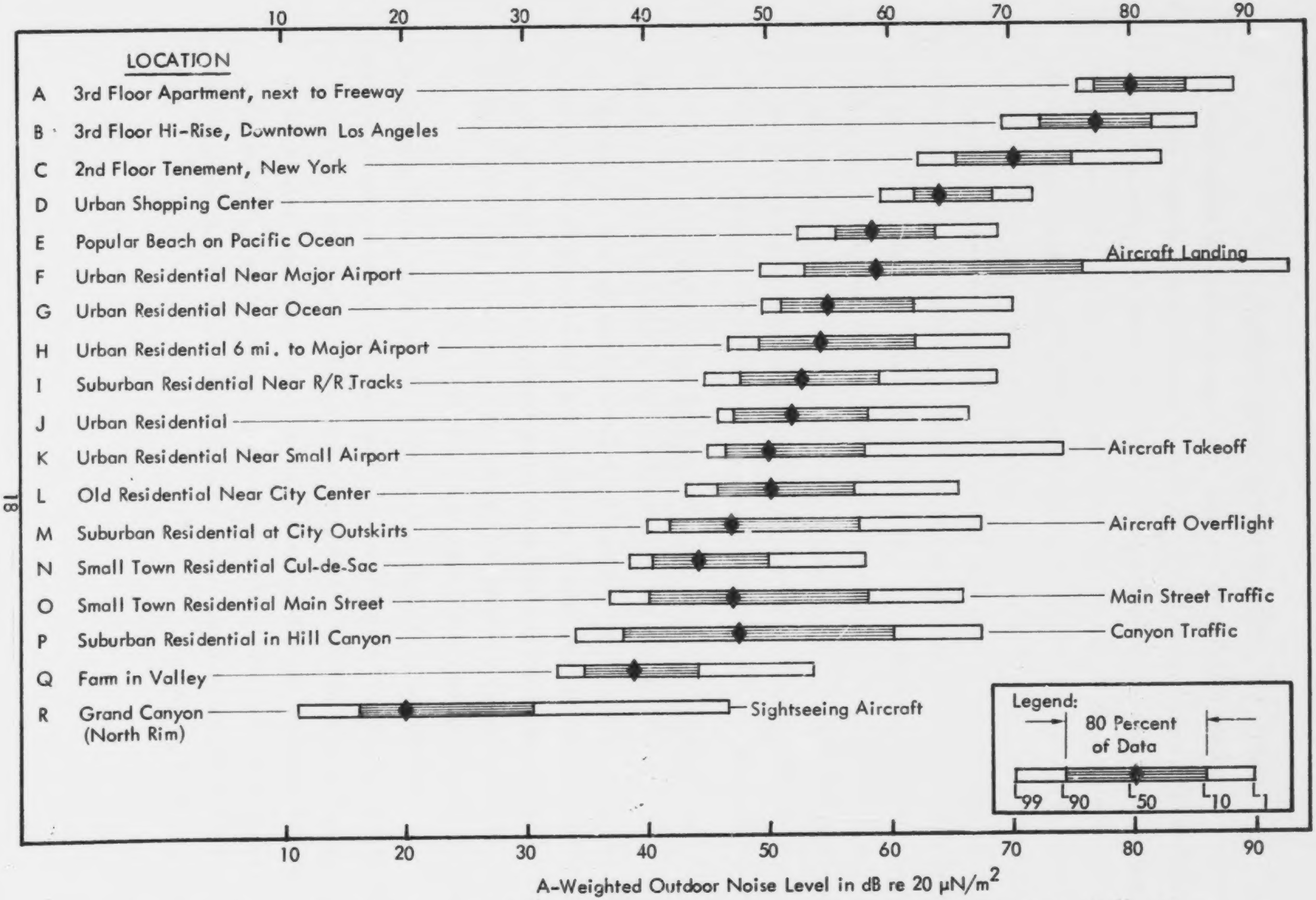


Figure 7. Daytime Outdoor Noise Levels Found in 18 Locations Ranging Between the Wilderness and the Downtown City, with Significant Intruding Sources Noted. Data are Arithmetic Averages of the 12 Hourly Values in the Daytime Period (7:00 a.m. - 7:00 p.m.) of the Levels Which are Exceeded 99, 90, 50, 10 and 1 Percent of the Time

The Grand Canyon measurement was made on the north rim, at a remote camping site. Its outdoor daytime residual noise level (L_{90}) of 16 dB(A) is near the internal noise threshold of the field measurement system and should be representative of the quietest locations in this country. The difference between this extremely low residual noise level and the much higher noise levels in the city is representative of the contribution of man and machine to the outdoor noise environment.

Figures 8 and 9 present similar data for the evening and nighttime periods. The order in which the locations are presented is the same as that used in Figure 7. However, unlike the data in Figure 7, where the L_{90} values increase monotonically from bottom to top, some irregularity can be seen among adjacent L_{90} values in Figures 7 and 8. This irregularity indicates that the magnitude of the variation of the noise with time throughout a 24-hour period is different at different locations.

The magnitudes of the variation in the L_{90}, L_{50} and L_{10} values for day, evening and night are presented in Figures 10 through 12. At two locations in Figure 10, both the evening and the nighttime values of the residual noise level exceed the daytime values because of crickets. At location P, which was in a quiet residential hillside canyon, the noise from the crickets was the dominant feature in the noise environment from 8:00 p.m. to 6:00 a.m. At the Grand Canyon, the crickets were of primary significance in the evening and early nighttime.

For the remainder of locations, except downtown Los Angeles, the evening noise levels were approximately equal to the daytime values, whereas the nighttime values were significantly lower. In downtown Los Angeles, the noise drops considerably in the evening, after commercial activity ceases.

As shown in these figures, the noise environments in city locations (e.g., downtown Los Angeles, tenement in New York, apartment adjacent to freeway and urban shopping center) are distinctly higher in level than are those in the suburban and urban residential areas. In this small sample of measurement locations, the average residual and median noise levels are over 20 dB greater at the city locations than in the detached residential housing areas in both daytime and nighttime, as seen in the comparisons in the first two columns of Table 3.

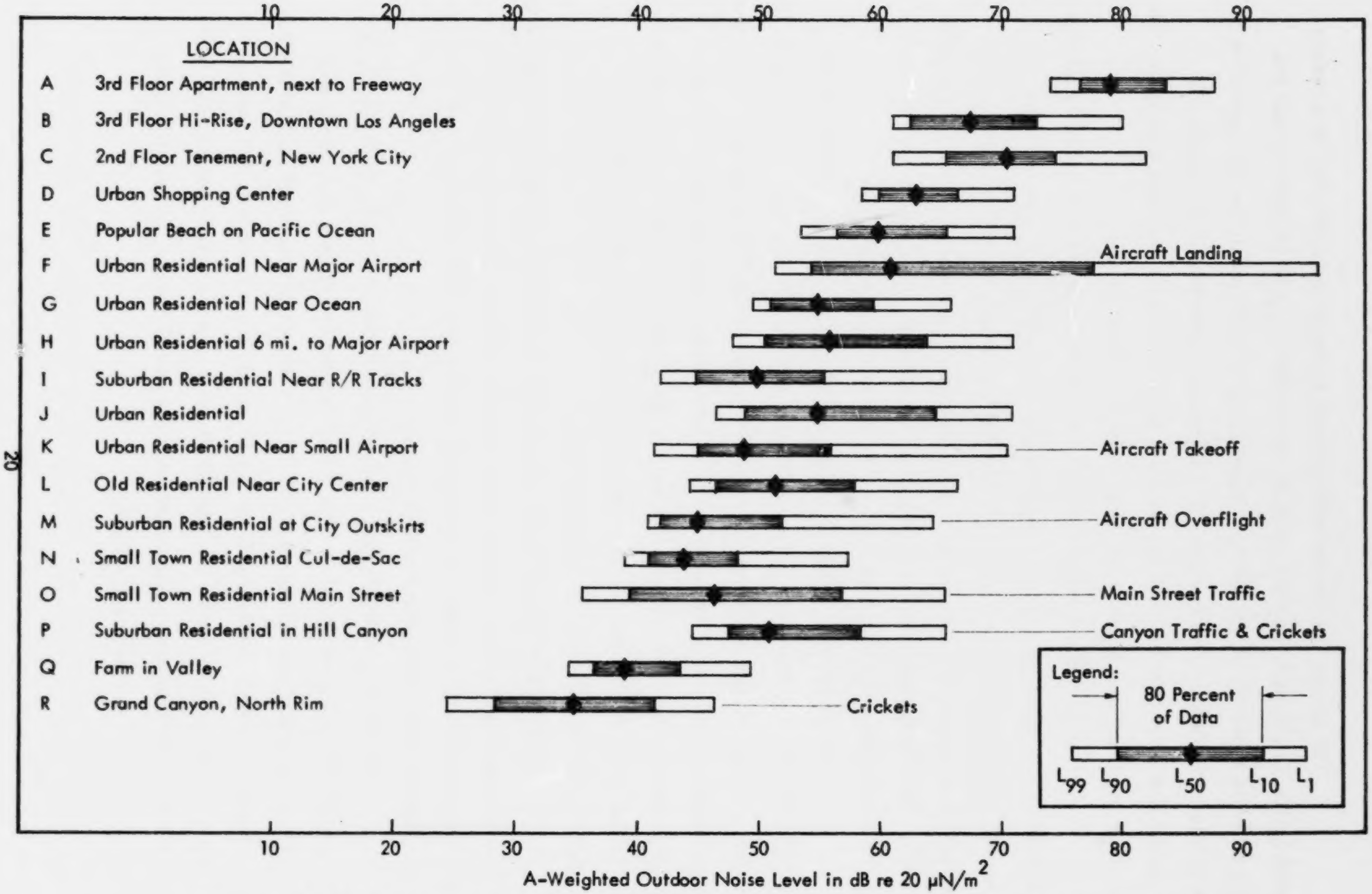


Figure 8. Evening Outdoor Noise Levels Found in 18 Locations Ranging Between the Wilderness and the Downtown City, with Significant Intruding Sources Noted. Data are Arithmetic Averages of the 3 Hourly Values in the Evening Period (7:00 p.m. - 10:00 p.m.) of the Levels Which are Exceeded 99, 90, 50, 10 and 1 Percent of the Time

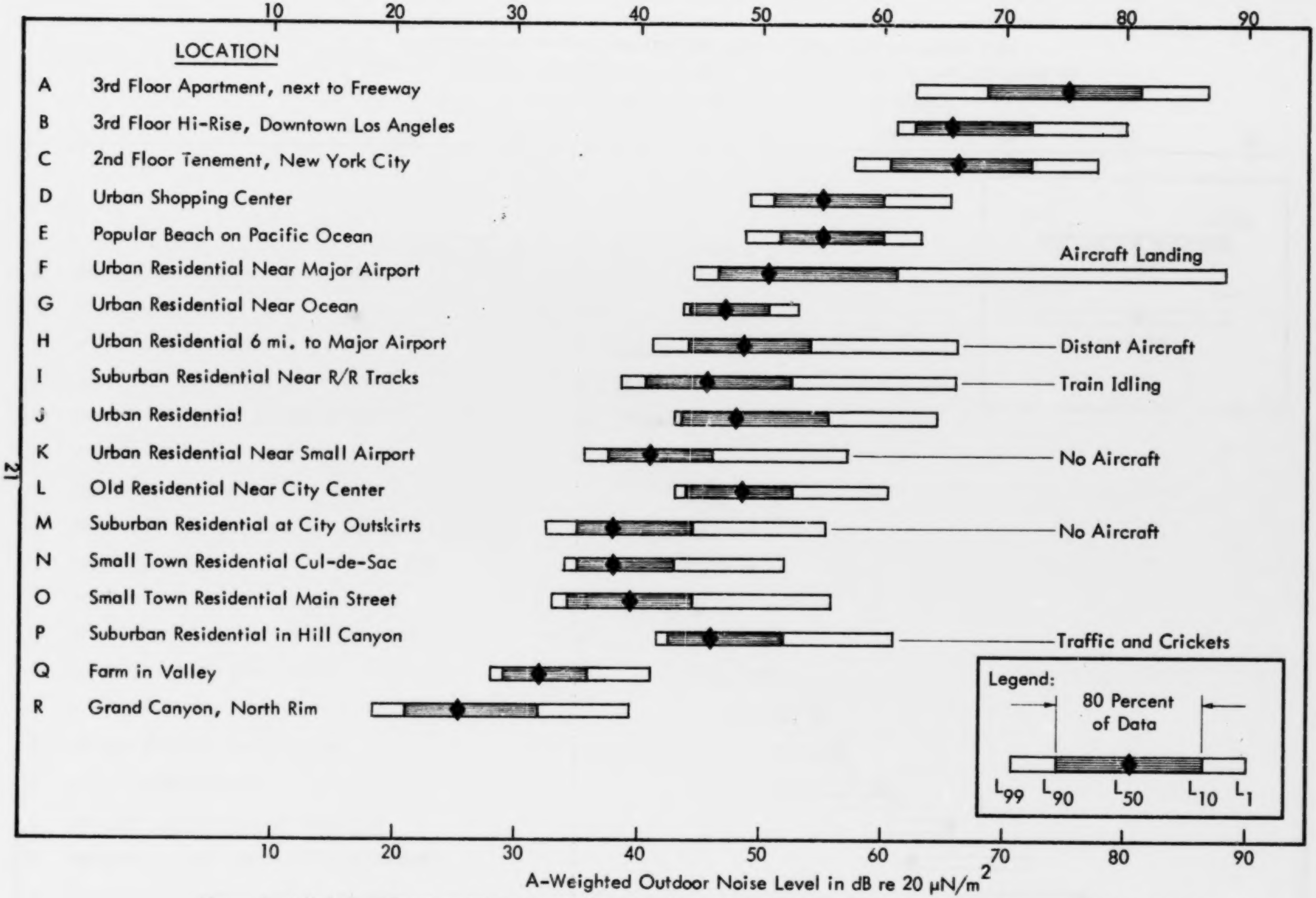


Figure 9. Nighttime Outdoor Noise Levels Found in 18 Locations Ranging Between the Wilderness and the Downtown City, with Significant Intruding Sources Noted. Data are Arithmetic Averages of the 9 Hourly Values in the Nighttime Period (10:00 p.m. - 7:00 a.m.) of the Levels Which are Exceeded 99, 90, 50, 10 and 1 Percent of the Time

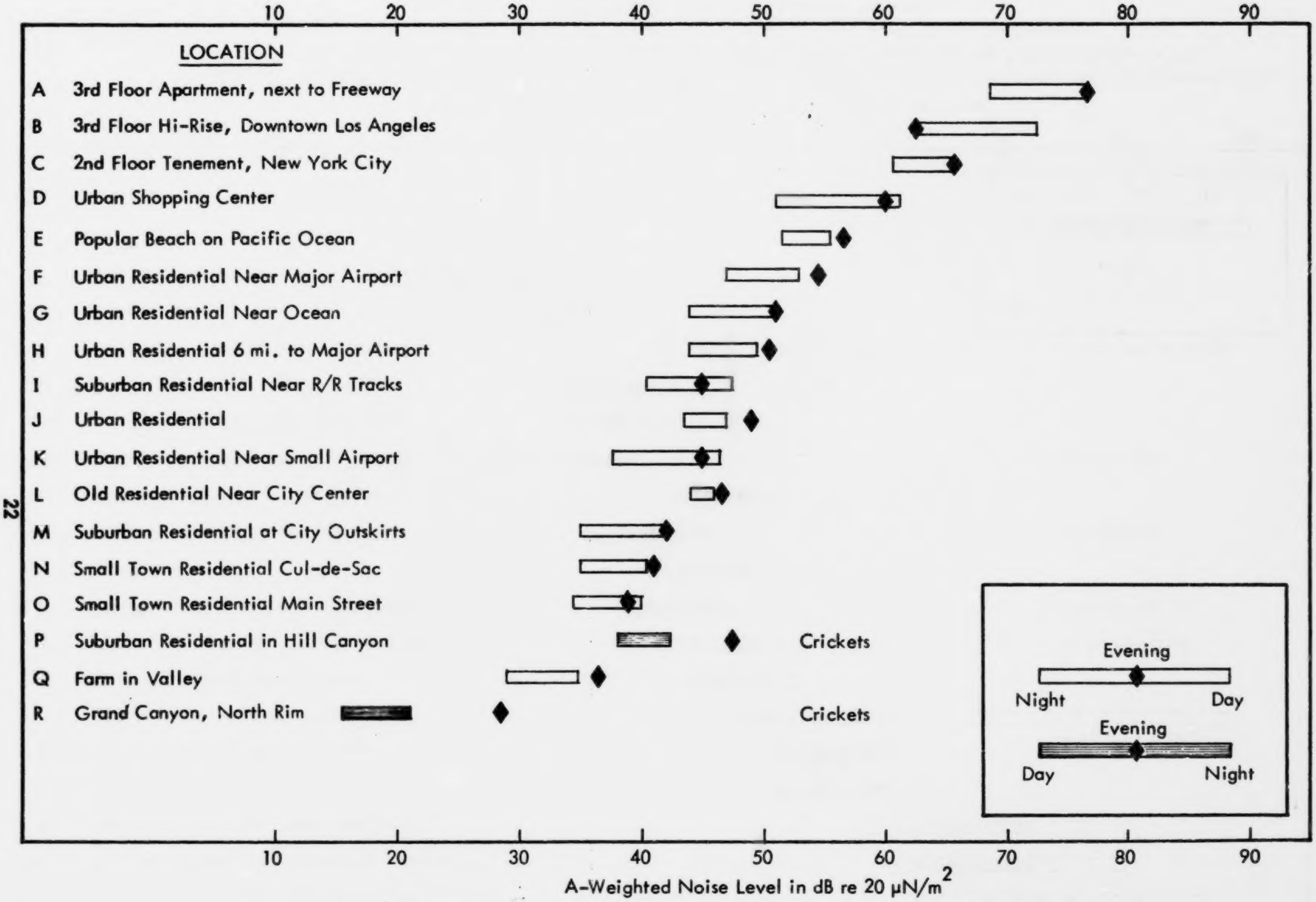


Figure 10. Residual Outdoor Noise Level (L_{90}) for Day, Evening and Nighttime for 18 Locations Ranging Between the Wilderness and the Downtown City

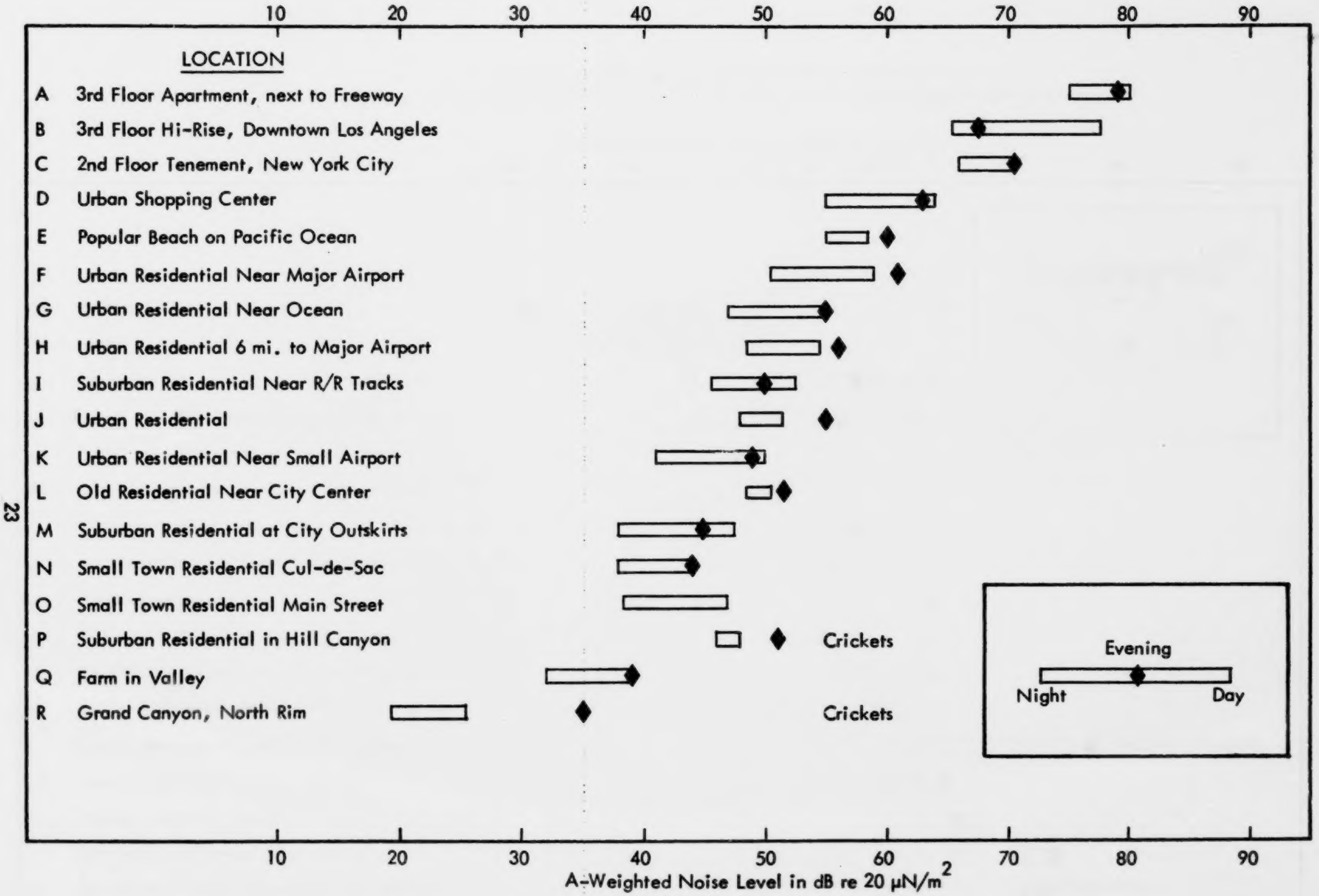


Figure 11. Median Outdoor Noise Level (L_{50}) for Day, Evening and Nighttime for 18 Locations Ranging Between the Wilderness and the Downtown City

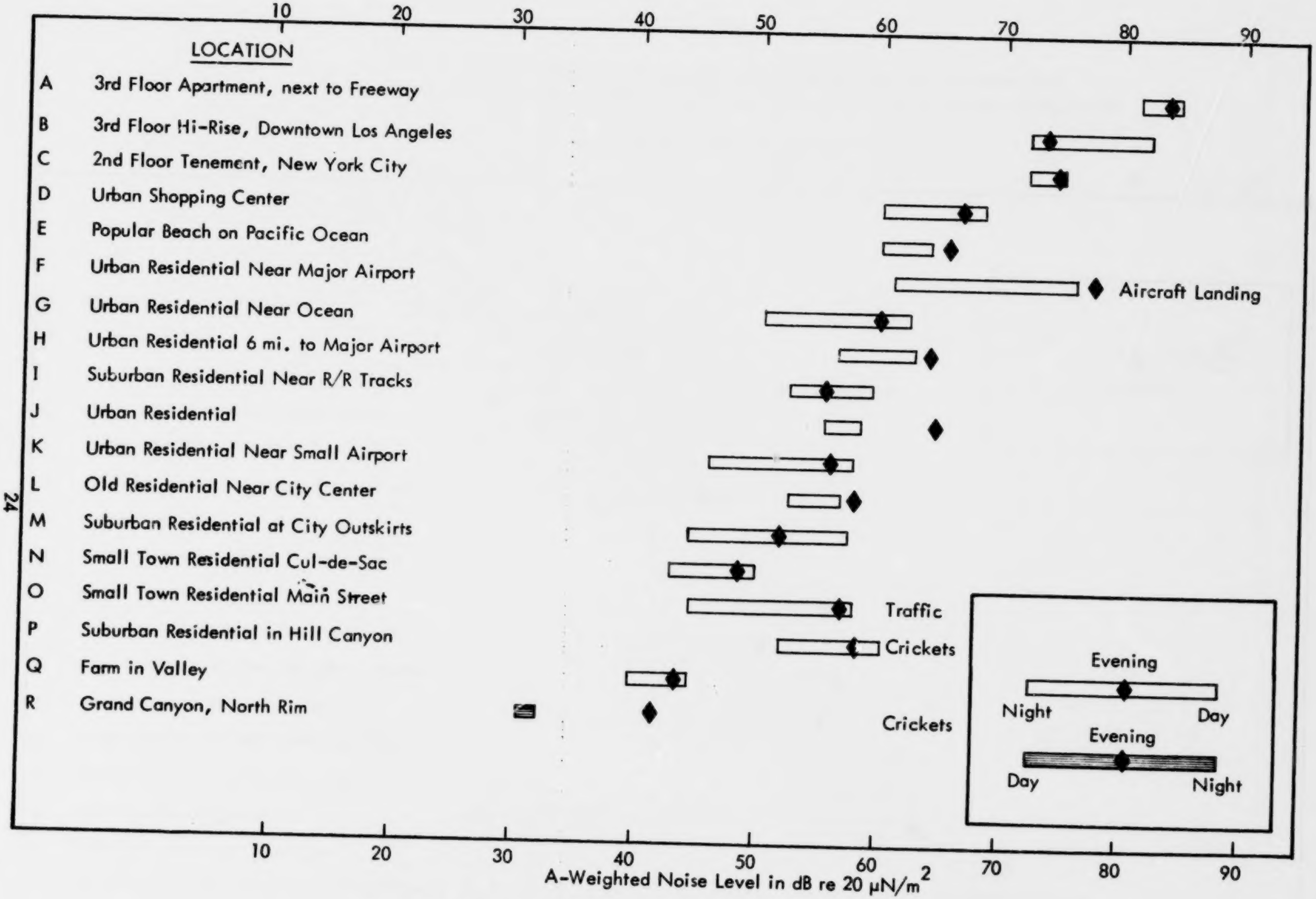


Figure 12. Outdoor Noise Level (L_{10}) for Day, Evening and Nighttime for 18 Locations Ranging Between the Wilderness and the Downtown City

Table 3

Comparison of Average Daytime and Nighttime Outdoor Noise Levels in City and Detached Housing Residential Areas. Data are Averages of Hourly Values During Indicated Period.

General Category	Average Daytime (7 AM-7 PM)			Average Nighttime (10 PM-7 AM)			Difference Between Day and Night	
	Range dB(A)	Arithmetic Mean dB(A)	Standard Deviation dB	Range dB(A)	Arithmetic Mean dB(A)	Standard Deviation dB	Average Difference dB	Standard Deviation of Difference dB
Residual Noise Level (L_{90})								
City (4 Locations)	61 to 77	69.1	6.1	51 to 69	60.8	6.3	8.3	2.1
Suburban and Urban Detached Housing Residential (11 Locations)	38 to 53	45.6	4.6	35 to 46	39.8	4.1	5.8	3.6
Median Noise Level (L_{50})								
City (4 Locations)	64 to 80	73.0	6.23	55 to 75	65.5	7.2	7.5	3.0
Suburban and Urban Detached Housing Residential (11 Locations)	44 to 59	50.9	4.1	38 to 50	44.2	4.3	6.7	2.6

The average of the differences between the daytime and nighttime residual noise levels at each of the 11 locations in the residential areas is 5.8 dB, slightly less than the 8.3 dB difference for the 4 city locations. However, in Table 4, a similar comparison of the differences between the maximum daytime and minimum nighttime residual noise levels showed a difference of 13 dB, averaged over the same 11 residential locations, and 15.2 dB for the city locations. This latter comparison between maximum and minimum levels gives full weight to the "quiet" nighttime period which was illustrated in the Figure 5 example of a "normal suburban residential" neighborhood.

The average value of the daytime residual noise level in residential areas was 45.6 dB (A) for this limited survey. This value lies on the borderline between the daytime residual noise level ranges chosen to represent "normal suburban" and "urban residential" areas, as given in Table 5. Since the qualitative descriptions of these 11 residential locations included four descriptive categories which ranged from "quiet suburban residential" to "noisy urban residential," it is not surprising that the average residual noise level for these locations is close to the average of the four categories in Table 5.

3.2 Relationships Among Various Measures of the A-Weighted Noise Level

There are several methods which have been used to report data which describe the outdoor noise environment.[14-22] In general, these methods are related to the type of instrumentation utilized for measurement, the purpose of the measurements, and sometimes to the time-varying characteristics of the noise which is measured. The degree of sophistication of the instrumentation ranges from the simple sound level meter, which is read directly by eye, to a complex system involving computer analysis of the statistics of the noise levels. The duration of the noise samples utilized for measurement has varied greatly, generally being relatively short for direct reading of sound level meters and sometimes almost continuous for graphic level or tape-recorder systems. Obviously, the reported results are influenced by the methods employed to obtain the data. Some indication of the degree of this influence can be obtained from the results of this survey, which include a wide variety of types of environments.

Table 4

Comparison of Maximum Daytime and Minimum Nighttime Hourly Outdoor Noise Levels in City and in Detached Housing Residential Areas

General Category	Maximum Daytime Hour 0700 - 1900			Minimum Nighttime Hour 2200 - 0700			Difference Between Day and Night	
	Range (dBA)	Arithmetic Mean (dBA)	Standard Deviation (dB)	Range (dBA)	Arithmetic Mean (dBA)	Standard Deviation (dB)	Mean Difference (dB)	Standard Deviation of Difference (dB)
Residual Noise Level (L_{90})								
City (4 Locations)	62 to 79	71	6.9	47 to 59	56	5.6	15	2.7
Suburban and Urban Detached Housing Residential (11 Locations)	42 to 56	49	4.3	27 to 42	36	5.5	13	4.4
Median Noise Level (L_{50})								
City (4 Locations)	66 to 83	76	7.2	51 to 70	62	7.1	14	4.0
Suburban and Urban Detached Housing Residential (11 Locations)	46 to 61	55	4.1	31 to 46	39	5.3	16	4.0

Table 5

Qualitative Descriptors of Urban and Suburban Detached Housing Residential Areas and Approximate Daytime Residual Noise Level (L_{90}). Add 5 dB to These Values to Estimate the Approximate Value of the Median Noise Level (L_{50}).

Description	Daytime Residual Noise Level in dB(A)	
	Typical Range	Average
Quiet Suburban Residential	36 to 40 inclusive	38
Normal Suburban Residential	41 to 45 inclusive	43
Urban Residential	46 to 50 inclusive	48
Noisy Urban Residential	51 to 55 inclusive	53
Very Noisy Urban Residential	56 to 60 inclusive	58

A comparison was made for each of the 24 hours at each site between the residual level read from the graphic level recording and the lower two statistical measures, L_{90} and L_{99}. A similar comparison was made between the maximum noise levels and the upper two statistical measures, L_{10} and L_1. The mean difference and standard deviation for each of the four comparisons is tabulated by location in Table 6.

The residual level for these data, as read on the graphic level recorder, averages approximately 0.9 dB below the L_{90} value and about 1.3 dB above the L_{99} value, with a standard deviation of about 2 dB in both cases. These results indicate that L_{90} is a reasonable choice for residual noise level, although an intermediate value between L_{90} and L_{99}, such as L_{95}, might be slightly better.

The results for the maximum noise level comparison indicate that L_{10} underestimates the maximum noise level by over 17 dB and L_1 underestimates it by about 9 dB.

The actual mean magnitudes of the underestimation of L_{10} range from approximately 9 to 30 dB, with a standard deviation of 7.6 dB for all of the 432 hourly samples. The range for the underestimations of L_1 is from approximately 4 to 14 dB, with a standard deviation of 4.8 dB. Clearly, L_{10} is a poor estimator of the maximum noise level at almost all locations, and L_1, although a much better estimator, cannot be considered accurate. Thus, whereas the residual noise is estimated with reasonable accuracy by a statistical measure between L_{90} and L_{99}, the maximum noise level is not estimated with equal accuracy by an equivalent statistical measure for higher levels. To obtain accuracy with the latter statistical measures, it would be necessary to consider levels which are exceeded 0.1 percent and 0.01 percent of the time.

Table 7 presents a similar comparison between differences between the arithmetic mean and the median (L_{50}). The results show excellent consistency between these two measures of the central tendency of the noise level, with the arithmetic mean averaging 0.78 dB greater than L_{50}, with a standard deviation for the 432 samples of 0.8 dB.

Table 6

Comparison of the Mean and Standard Deviation of the 24 Hourly Differences Between Graphic Level Recorder and Statistical Measures of the Residual and Maximum Noise Levels at Each of 18 Locations

Location	Residual Noise Level Comparison* in dB				Maximum Noise Level Comparison** in dB			
	24 Hour Mean $RL-L_{99}$	$\sigma_{RL-L_{99}}$	24 Hour Mean $RL-L_{90}$	$\sigma_{RL-L_{90}}$	24 Hour Mean $ML-L_{10}$	$\sigma_{ML-L_{10}}$	24 Hour Mean $ML-L_{1}$	$\sigma_{ML-L_{1}}$
A	-0.85	2.60	-3.94	4.65	9.70	3.09	5.08	2.62
B	-0.15	2.56	-2.44	1.90	9.48	4.52	3.77	2.97
C	2.05	1.19	-1.50	1.16	17.62	4.96	11.04	4.14
D	1.75	1.65	0.17	1.35	13.50	5.45	9.28	4.78
E	1.87	1.24	-1.20	0.51	12.68	3.97	8.07	3.39
F	2.28	1.24	-0.50	1.55	30.20	8.88	8.78	3.87
G	-2.33	1.37	-3.41	1.89	10.40	3.39	4.10	3.45
H	2.18	1.26	-0.44	1.29	14.75	2.45	6.66	2.07
I	1.04	1.10	-1.68	1.17	21.78	6.12	10.87	4.21
J	1.51	0.98	0.28	1.11	16.15	5.02	7.85	3.61
K	1.68	1.20	-0.19	0.84	24.65	6.16	10.36	4.18
L	1.62	1.20	-0.35	1.19	18.61	3.51	10.42	3.19
M	2.08	1.29	0.29	1.07	22.41	7.00	12.26	5.87
N	1.99	1.21	0.37	0.66	23.02	5.66	14.32	5.19
O	1.79	1.42	-0.90	1.94	19.51	5.37	9.73	3.70
P	2.21	1.81	-0.40	2.57	19.24	3.90	11.35	3.07
Q	2.01	1.65	-0.10	1.10	16.65	4.37	9.24	4.86
R	1.28	1.56	-0.39	2.37	18.68	8.70	7.20	4.90
Average All Locations	1.33	1.95	-0.91	2.19	17.73	7.63	8.91	4.85

*Residual Noise Level Read from Graphic Level Recordings is abbreviated RL

**Maximum Noise Level Read from Graphic Level Recordings is abbreviated ML

Table 7

Comparison of the Mean and Standard Deviation of the 24 Hourly Differences Between the Arithmetic Mean and the Median L_{50} Measures of the Outdoor Noise Level in dB

Location	Mean* Difference	Standard Deviation	Location	Mean* Difference	Standard Deviation
A	0.09	0.31	J	0.78	0.51
B	0.40	0.45	K	1.01	0.59
C	0.18	0.27	L	0.49	0.32
D	0.32	0.24	M	1.28	0.57
E	0.48	0.26	N	0.58	0.31
F	2.68	0.66	O	0.98	0.67
G	0.66	0.51	P	0.80	0.91
H	0.90	0.39	Q	0.53	0.47
I	0.61	0.57	R	1.22	1.21
Composite of A through R				0.78	0.80

*Mean of 24 Values of (Arithmetic Mean − L_{50}).

The difference between averaging hourly values of the various statistical measures throughout a period and computing the same values from the ensemble of all data obtained during the period was discussed in Section 2.2 for an example at one location. A comparison of the 24-hour period results for the 18 locations, presented in Figures 13 and 14, shows that significant differences exist at most locations between the two methods of computation. The differences are greatest for the lower level statistical measures, particularly L_{99}, with the value computed for the 24-hour ensemble ranging from 2 to 10 dB less than the value computed by averaging the 24 hourly values.

One of the most important decisions in designing surveys of the outdoor noise environment is the choice of sampling technique. This factor is one of the greatest

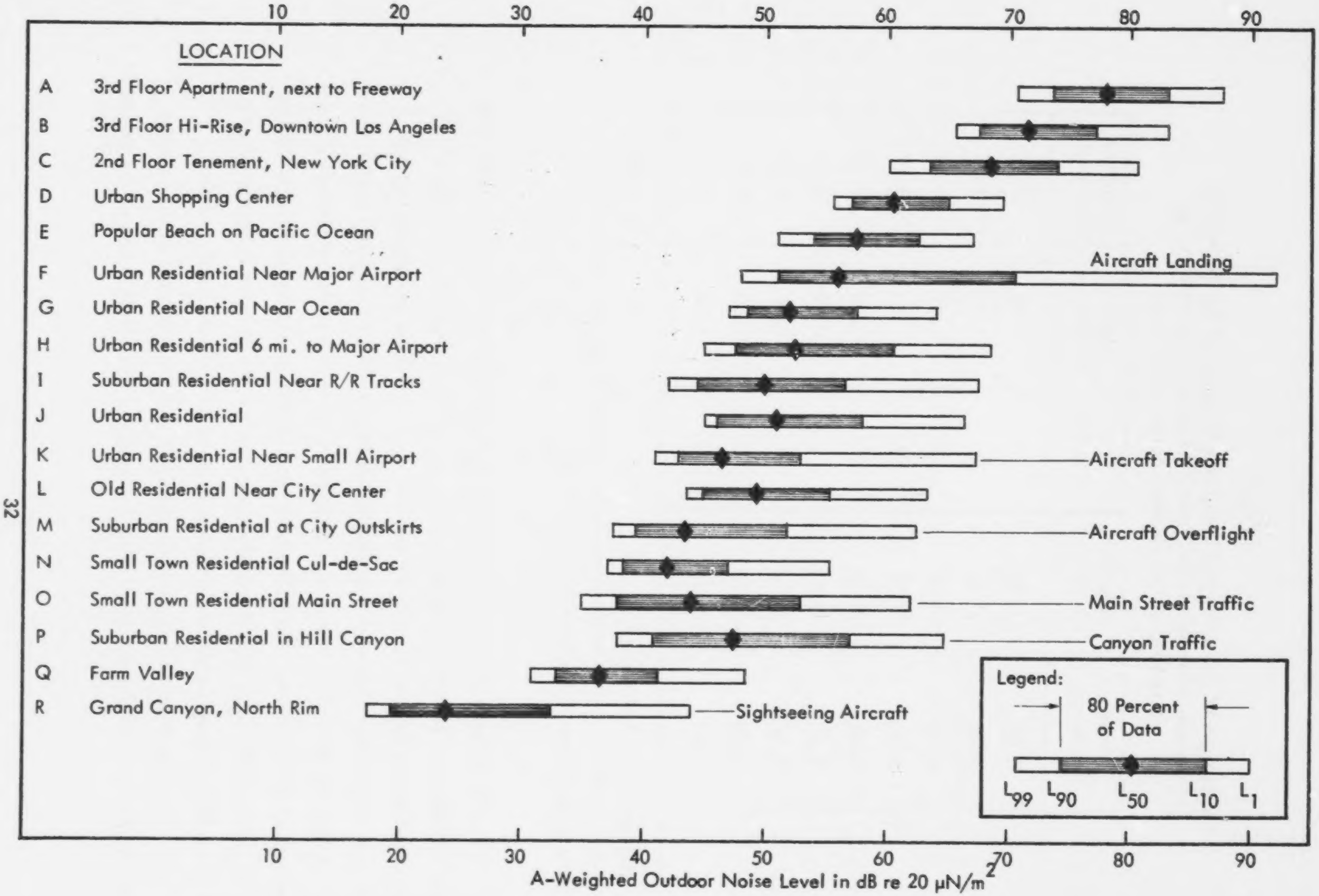


Figure 13. 24-Hour Outdoor Noise Levels Found in 18 Locations Ranging Between the Wilderness and the Downtown City, with Significant Intruding Sources Noted. Data are Arithmetic Averages of the 24 Hourly Values in the Entire Day of the Levels Which are Exceeded 99, 90, 50, 10 and 1 Percent of the Time

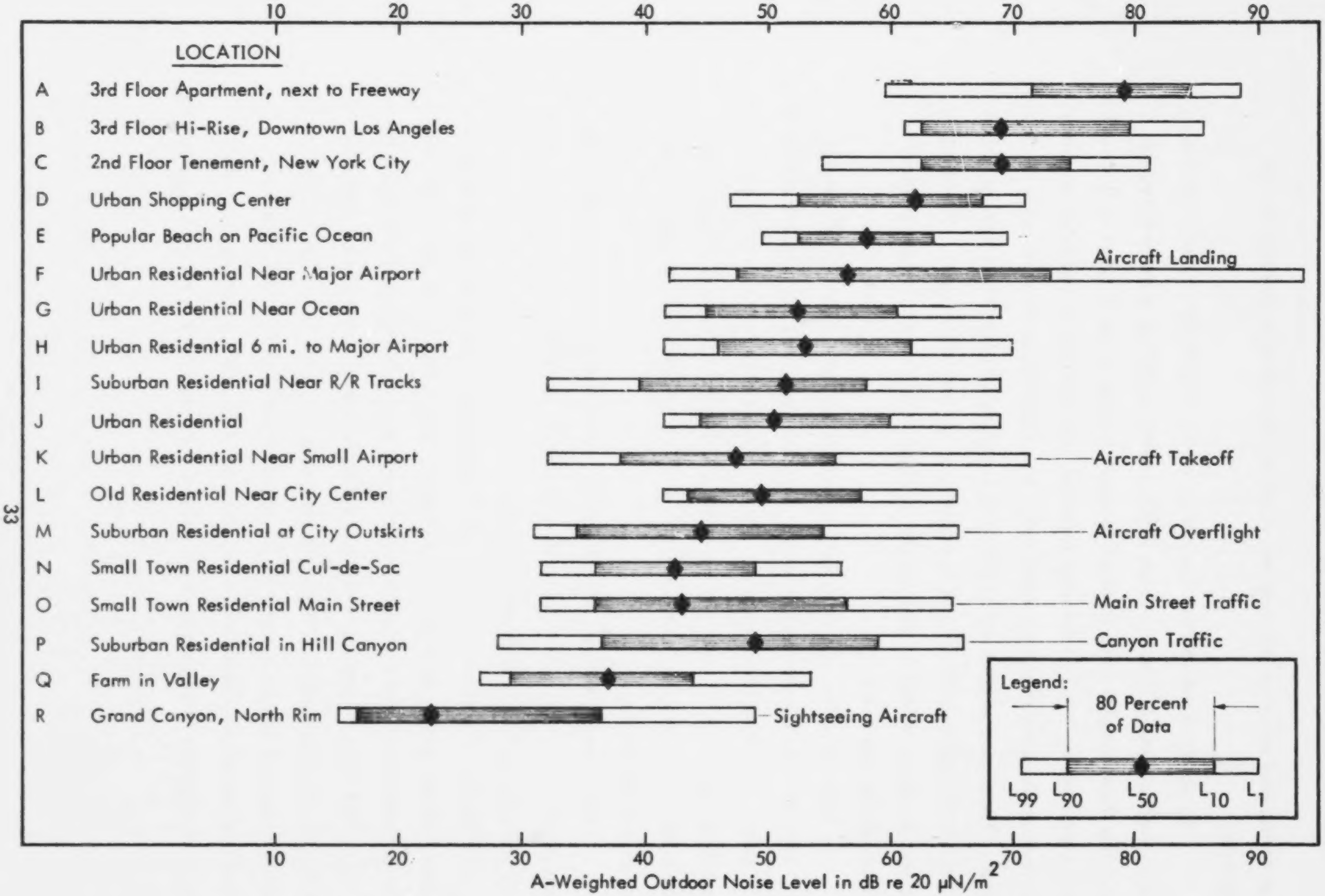


Figure 14. 24-Hour Outdoor Noise Levels Found in 18 Locations Ranging Between the Wilderness and the Downtown City, with Significant Intruding Sources Noted. Data are the Levels Which are Exceeded 99, 90, 50, 10 and 1 Percent of the Time from the 24-Hour Ensemble

variables among past noise surveys and may have significant consequences for the resulting data.

To obtain a preliminary evaluation of the magnitude of the errors associated with various sample lengths, three 3200-second recordings were selected for analysis. The three samples were selected to cover a wide range of types of fluctuations in level. One sample, from the freeway location, was selected to represent an almost gaussian and steady-state intruding noise which was expected to be reasonably stationary throughout. The second sample was selected to be typical of many suburban neighborhoods with a combination of local single events plus aircraft overflights. The third example was an urban residential neighborhood which had four significant aircraft noise events during the hour.

Each recording was statistically analyzed in 64 sequential 50-second samples. The raw data for sequential pairs of samples were then combined and used to obtain 32 values for 100-second samples. Then, the raw data for sequential pairs of 100-second samples were combined into sixteen 200-second samples and analyzed. This combinatorial process was continued until the entire 3200-second recording was analyzed as a single sample.

The average difference between the value of a given measure from the 3200-second sample and the value for each of the other samples was calculated. The mean and standard deviation of these differences is given for L_1, L_{10}, L_{50}, L_{90}, and L_{eq} in Table 8. The mean difference for all measures of the freeway noise (A) is less than 1 dB for sample durations of 100 seconds and greater. To obtain the same accuracy at locations M and K, requires a minimum sample duration of 800 seconds.

The largest sampling errors are exhibited by L_1, as might be expected. At position K, the mean error in L_1 ranges between about 9 and 19 dB, with respective standard deviations of about 11 and 8 dB for sample lengths of 400 and 50 seconds. The significance of these large mean errors in L_1 is that only a few of the samples are affected by the highest level single-event noises. The most stable value is L_{50}, which

Table 8

Accuracy in Estimating Various Hourly Noise Level Values from Samples of Differing Duration

Location	Sampling		L_1		L_{10}		L_{50}		L_{90}		L_{eq}	
	Number	Duration (Seconds)	Mean*	σ**	Mean	σ	Mean	σ	Mean	σ	Mean	σ
A) Freeway Noise *** Between 10 & 11 p.m.	64	50	1.67	2.65	.02	1.31	- .09	.68	- .15	.90	.12	1.03
	32	100	.85	2.33	.01	.99	- .05	.46	- .17	.78	.06	.74
	16	200	.36	1.54	- .07	.64	- .02	.30	- .11	.57	.03	.49
	8	400	.10	.64	- .06	.41	- .01	.24	- .09	.46	.01	.35
	4	800	- .04	.38	- .06	.34	.00	.19	- .09	.44	.01	.27
	2	1600	.00	.02	.00	.13	.00	.10	- .04	.29	.00	.14
M) Normal Suburban Residential at City Outskirts with Aircraft Over-flights Between 5 & 6 p.m.	64	50	6.41	7.31	2.59	5.34	- .59	3.65	-1.54	2.63	3.44	5.21
	32	100	3.41	6.27	2.29	4.85	- .38	2.89	-1.11	2.16	2.32	4.43
	16	200	1.48	4.09	1.74	4.44	- .20	2.26	- .94	2.04	1.54	3.59
	8	400	1.18	3.44	1.20	4.24	- .17	1.46	- .63	1.66	1.18	3.22
	4	800	.94	2.24	.98	3.61	- .19	1.23	- .43	1.33	.83	2.72
	2	1600	.65	2.21	.72	2.85	- .10	.60	- .01	.20	.00	.02
K) Urban Residential Near Small Airport Between 5 & 6 p.m.	64	50	18.86	8.22	2.82	7.75	-1.36	5.79	-2.08	4.04	10.84	7.05
	32	100	16.48	9.40	1.35	8.74	-1.04	4.42	-1.23	2.49	9.67	7.75
	16	200	12.67	10.39	- .57	8.11	- .49	2.43	- .30	.72	7.40	8.02
	8	400	8.98	11.35	-1.10	5.85	- .17	1.73	- .19	.53	4.89	7.71
	4	800	- .07	1.99	- .13	1.35	.13	1.13	- .10	.39	.21	1.41
	2	1600	- .06	1.59	- .06	.32	.06	.40	- .01	.09	.11	.99

* Mean denotes average difference between the 3200 second value of the quantity measured and the mean value of all the samples for the stated duration.

** σ is the standard deviation of the samples about this mean value.

*** Graphic level recordings of these sample "hours" are given in Appendix A.

has only a small mean error for all sample lengths, as expected. However, to obtain a standard deviation of less than 1 dB for L_{50} required a sample length greater than 800 seconds at both positions M and K, although 50 seconds were adequate for this result at position A.

The potential magnitude of the errors in estimation of the statistical measures of the higher noise levels is obviously large for any noise environment which is characterized by significant single events. Consequently, such measures should be applied with great caution unless the fraction of time during which data are acquired is at least 25 percent of the total time in the period examined, and preferably 50 percent of the total time. However, even with this latter constraint, the standard deviation for L_1 and L_{10} exceeds 2 dB at position M and is almost 2 dB for L_1 at position K. Assuming these errors are normally distributed, a standard deviation of 2 dB for a given sample length implies that the result for a single measurement has a 95 percent probability of being within ± 4 dB of the true value.

3.3 Typical Outdoor Daytime Residual Noise Spectra

Typical outdoor daytime residual noise spectra are given in Figures 15 and 16. All exhibit the same general shape, with their maxima at low frequency.

Figure 17 shows spectra for 8 residential locations, normalized by their individual A-weighted levels. The relatively small range of these relative levels, particularly above 300 Hz, is indicative of their essential similarity. With the exception of the effects of wildlife, this residual noise is primarily due to automotive transport. The low frequency maximum results from the integrated effect of automobile noise over an extended area.[23] The remainder of the spectrum is controlled by automotive noise from a more limited area because atmospheric attenuation and shielding reduce the higher frequency noise transmission. Consequently, the medium and high frequency portion of the spectrum is relatively similar to the spectra for nearby automobiles, illustrated in Figure 18.

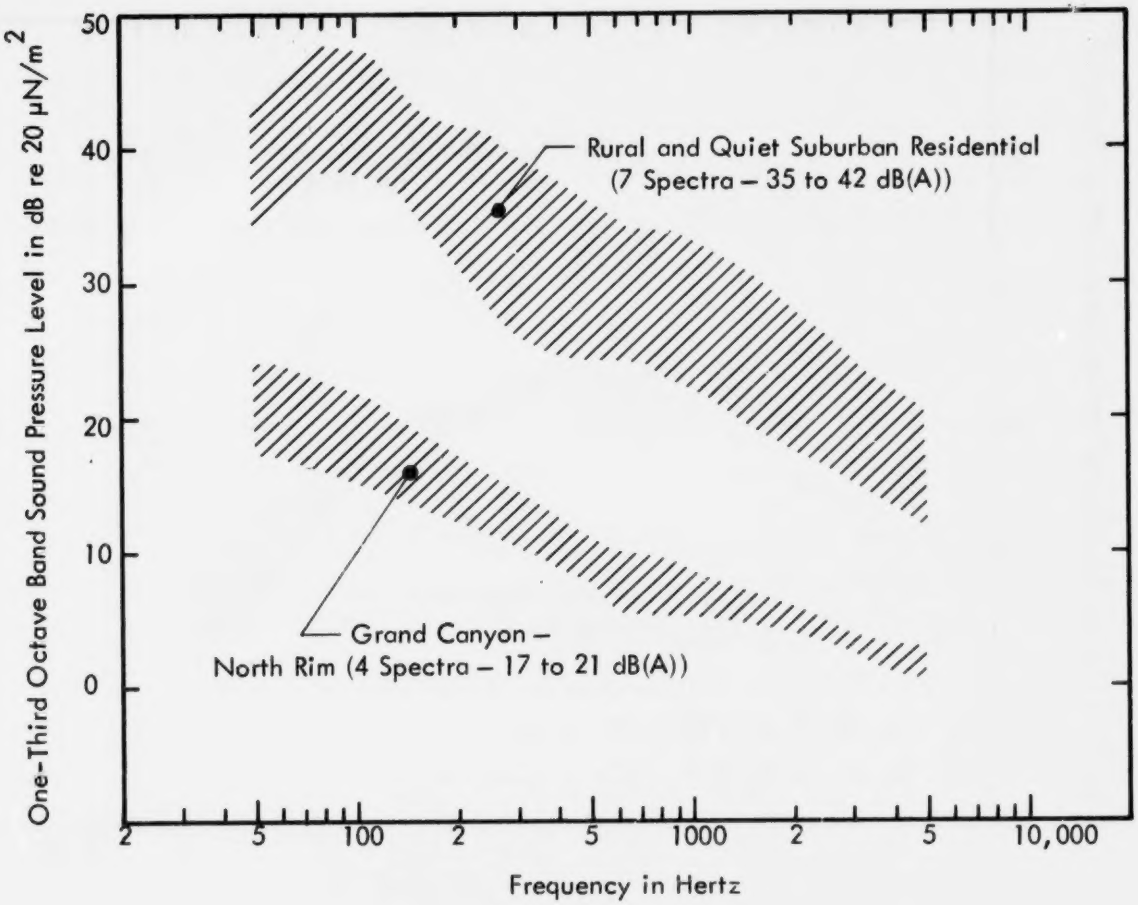


Figure 15. Examples of Daytime Residual Noise Spectra in Low Noise Level Areas (High Frequency Levels at Grand Canyon Site May be Instrument Noise)

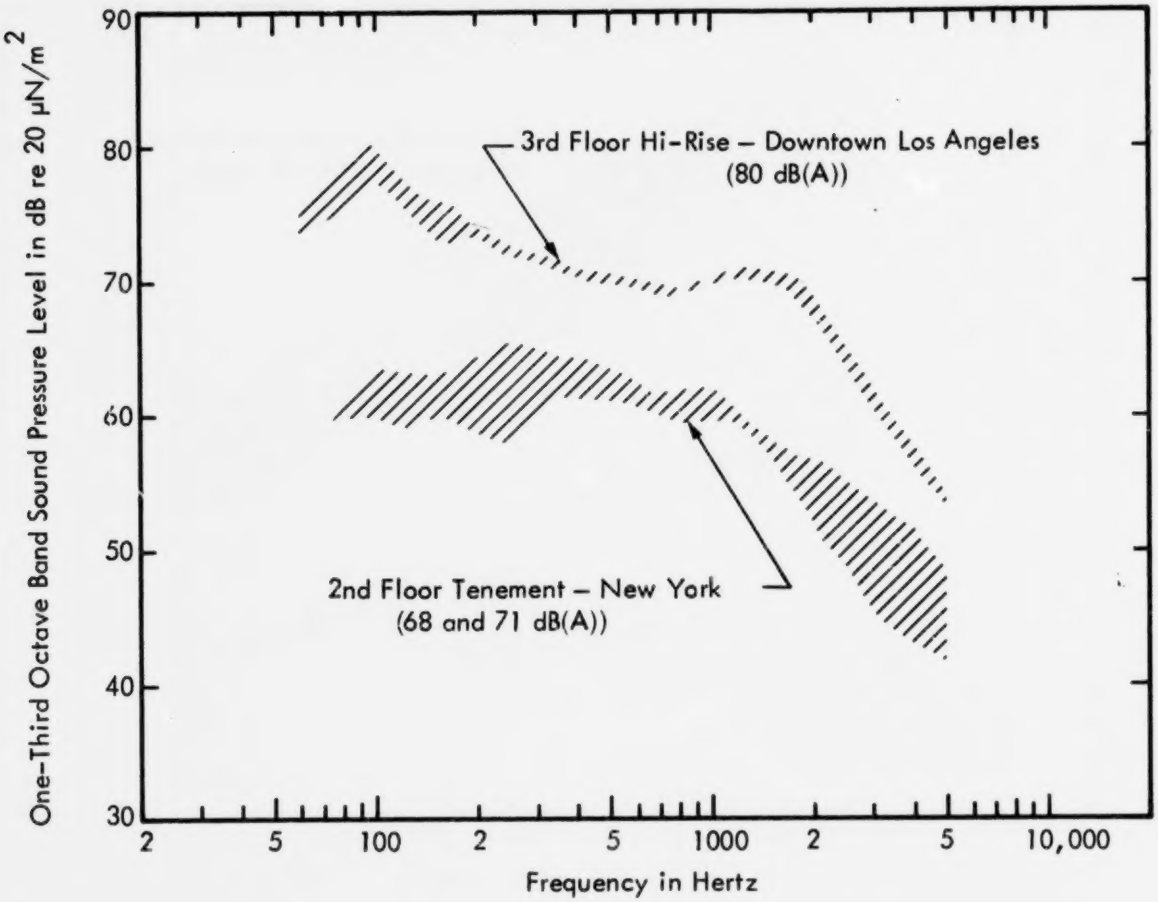


Figure 16. Examples of Daytime Residual Noise Spectra in Cities

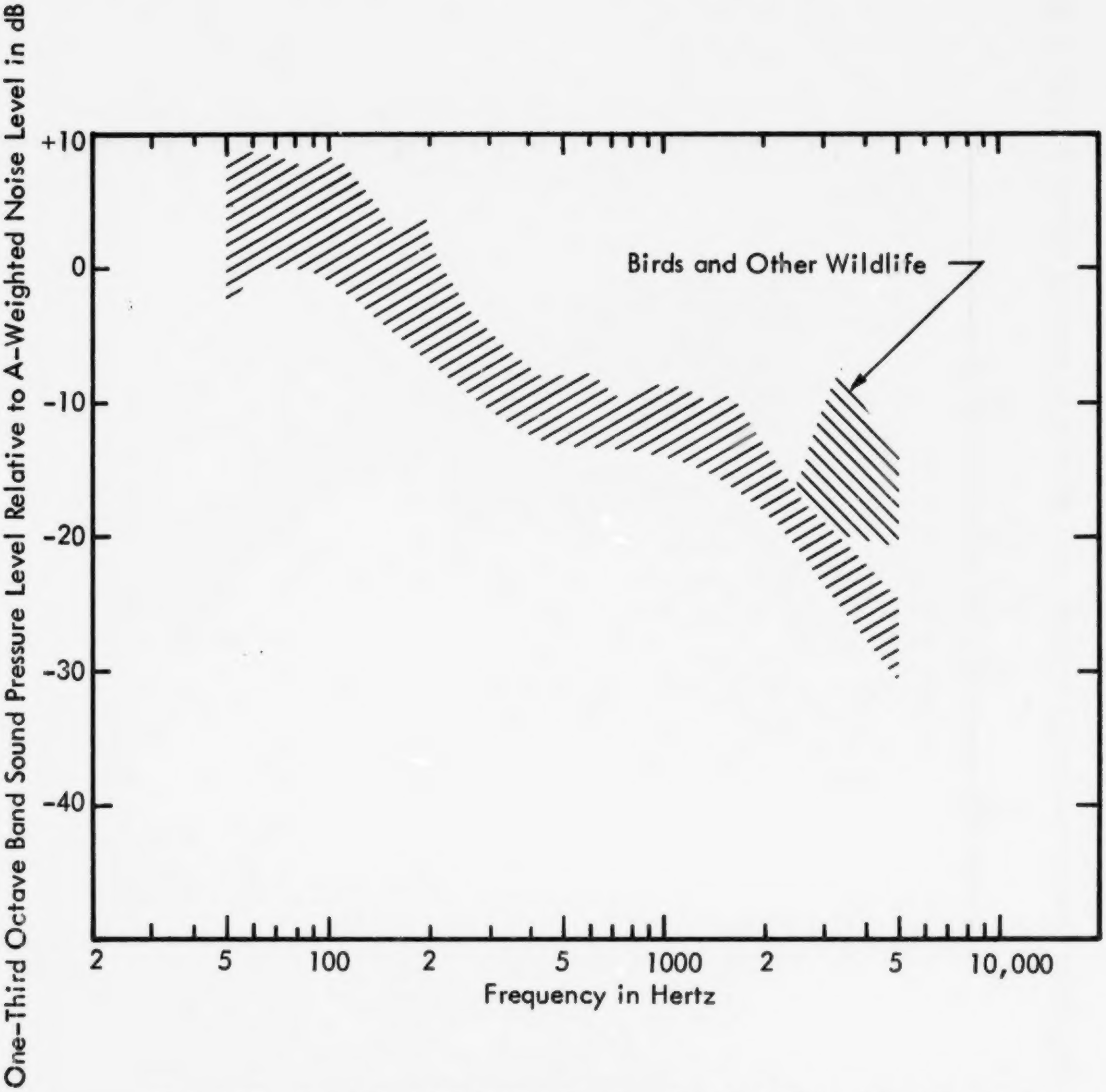


Figure 17. Examples of Relative Daytime Residual Noise Level Spectra at 8 Locations Encompassing Normal Suburban to Noisy Urban Residential Neighborhoods with Noise Levels Ranging from 43 to 55 dB(A)

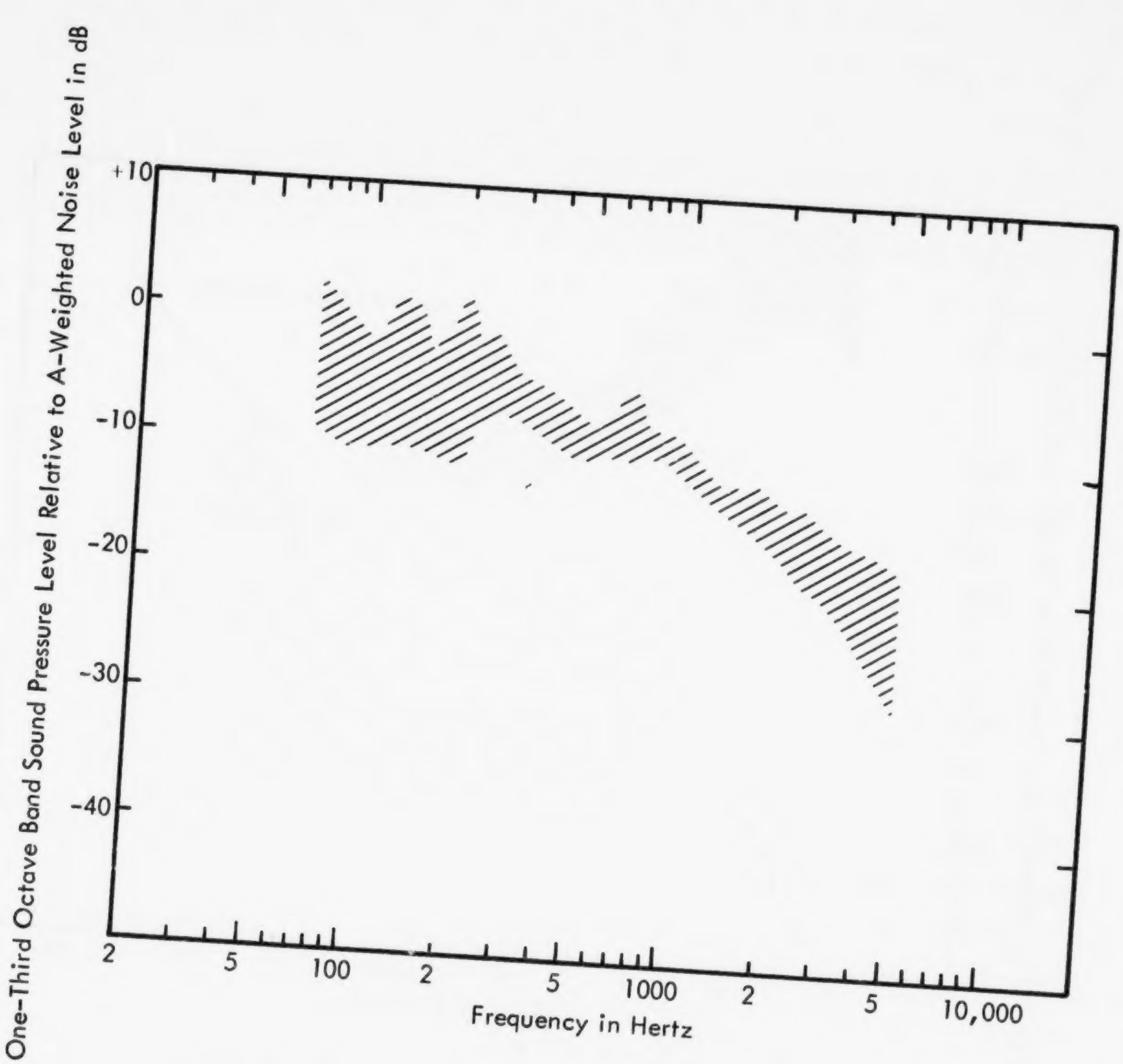


Figure 18. Range of the Relative Maximum Noise Spectra Measured During the Passby of 10 Standard Passenger Automobiles Driving on Local Residential Streets

4.0 INTRUDING NOISES

There are two basic types of identifiable intruding noises which increase the outdoor noise level above the residual noise level – steady or quasi steady state constant level noises and intermittent single event noises. A steady or nearly constant level noise intrusion may result from a nearby freeway, industry, or a neighbor's residential air conditioner. The intermittent single event noise is exemplified by the noise from an aircraft flyover, a single car pass-by, or a dog who barks for a short time. Both types of identifiable intruding noises can represent noise pollution.

4.1 Constant Level Noise Intrusions

One of the best known examples of constant level noise intrusion is the noise environment within a busy city. The high daytime noise levels within the city make it difficult to have an intelligible face-to-face conversation at normal voice levels outdoors. For example, if the outdoor noise level is 76 dB(A), a condition commonly encountered when walking along downtown city sidewalks, it is necessary to talk in a raised voice to achieve intelligibility at a 2-foot distance.

The maximum distances for intelligible conversation at various voice levels are given in Figure 19. These criteria have been applied to the outdoor daytime median noise levels measured at each of the 18 locations in the exploratory survey to determine the maximum distances for intelligible conversation at each location. The median noise level, rather than the residual noise level, has been selected for evaluating the effects of the outdoor noise environment on speech communication since the median noise level more nearly represents the "typical" or "average" noise environment. The calculated distances, summarized in Figure 20, illustrate the restrictions in voice communication distances which accompany the higher noise levels in the city.

Similar calculations show that the maximum distances for normal voice conversation outdoors in a "very noisy urban residential" area are 3 to 5 feet, according to the range of noise levels for this category in Table 5 in Section 3.1. Clearly, areas with even higher outdoor median noise levels have very limited utility for outdoor conversation, and consequently are poorly suited for detached housing land use. Also, the

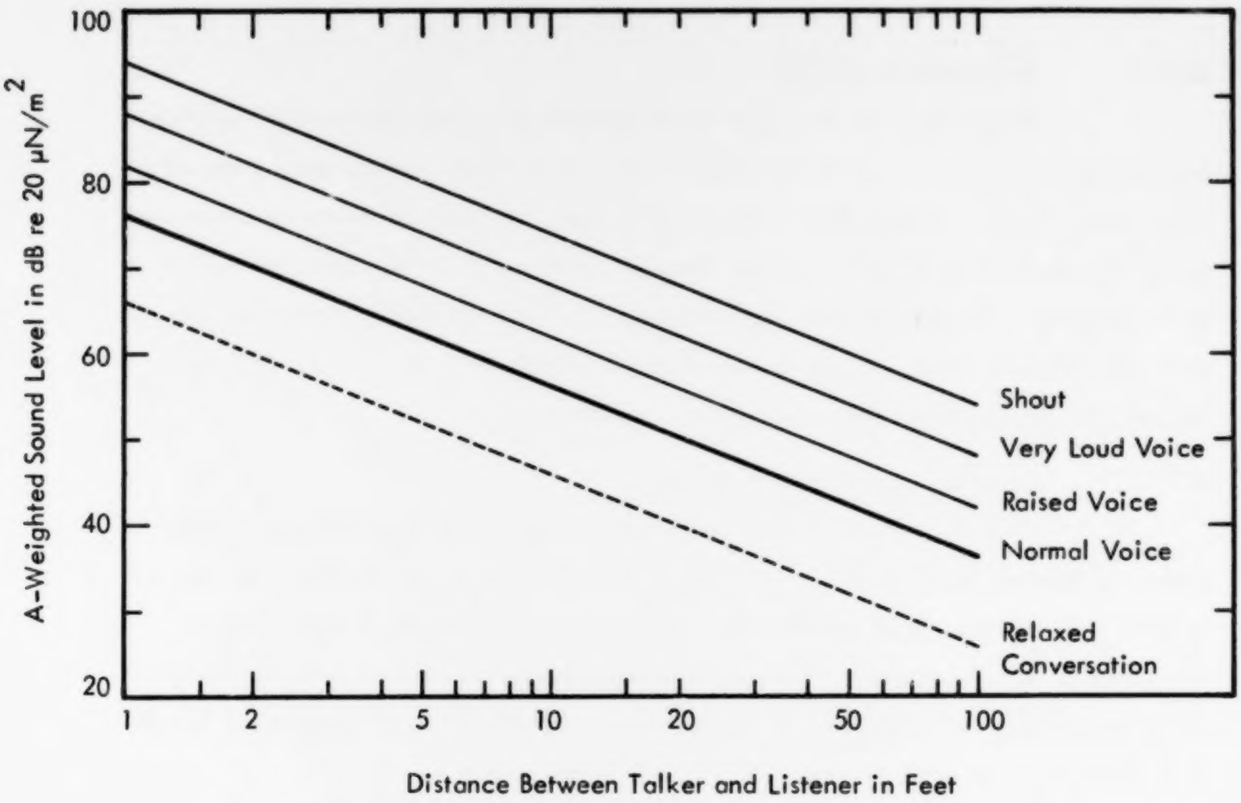


Figure 19. Maximum Distance Between Talker and Listener for Just Intelligible Conversation and for Highly Intelligible Relaxed Conversation as a Function of Noise Level[24,25]

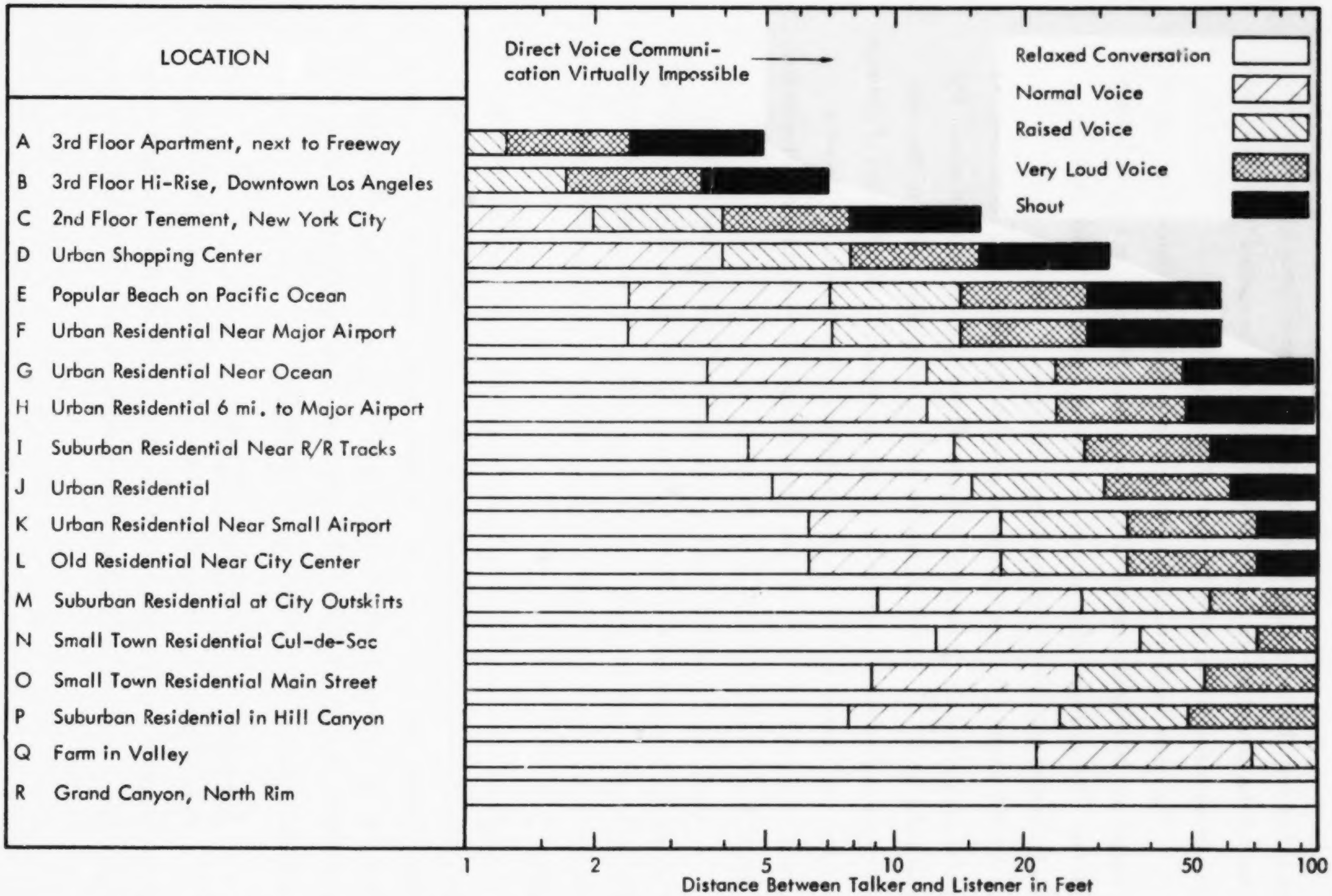


Figure 20. Estimated Maximum Distances Between Talker and Listener That Just Permit Intelligible Conversation and Those That Enable Relaxed Conversation When the Outdoor Noise Level Equals the Daytime Median Noise Level (L_{50}) at Each of the 18 Locations

noise associated with the "very noisy urban residential" area of Table 5 is sufficiently high to restrict the amount by which doors and windows can be opened if one is to retain a desirable indoor noise environment for relaxed conversation.

The noise levels associated with the "quiet suburban residential" area of Table 5 permit just intelligible normal voice conversation at distances ranging between 30 and 50 feet. The ability to communicate in a normal voice over these distances is very useful in a neighborhood with large lots. However, if the noise level is so low that the distance for intelligible conversation in normal voice approaches the distances between neighbors, it becomes difficult to have a private conversation. The noise level calculated[26,27] to mask speech for normal voice level (male) so that only 5 percent of the sentences are intelligible,is given in Figure 21, as a function of distance between talker and listener for two assumed conditions. There is a 9 dB difference between these two conditions and the lower value probably is more representative of the typical situation which generally has some shielding.

These results indicate that the residual noise level required to obtain privacy for neighbors separated by a 50-foot distance would have to be of the order of 41 dB(A), assuming random orientation of the talker relative to the neighbor and 5 dB of shielding. This residual noise level is approximately that of the normal suburban community.

These considerations of speech intelligibility and privacy suggest that there is both a maximum and a minimum bound to the outdoor noise levels which are compatible with reasonable enjoyment and full use of patios, porches and yards. The upper bound for speech intelligibility appears to be in the range of the "very noisy urban residential" category of Table 5, and the lower bound for speech privacy is a function of the distance and shielding between neighbors.

4.2 Intermittent Single Event Noise Intrusions

A great number of intermittent single event noises were measured during the exploratory survey. A brief sampling of the various types of noises and their maximum noise levels at some of the 18 measurement locations is given in Table 9, and some

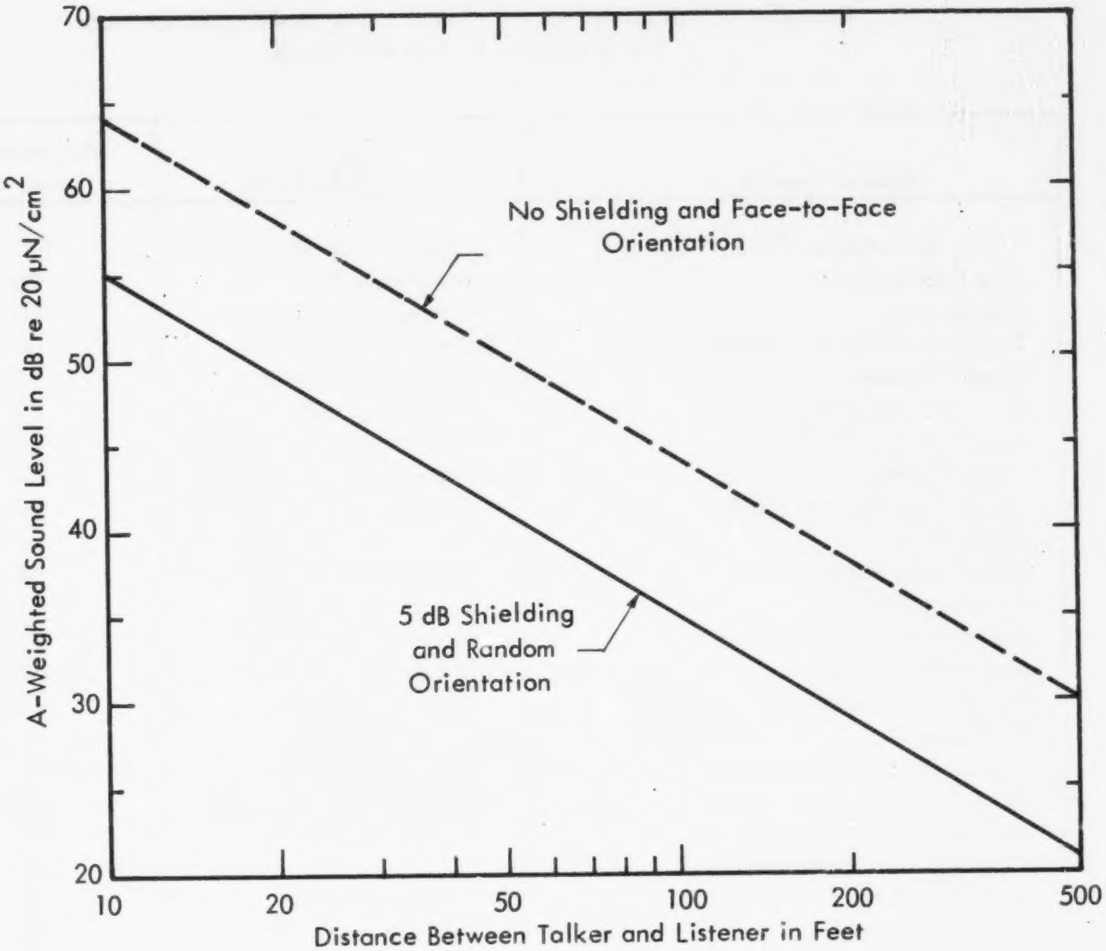


Figure 21. Noise Level Required to Mask Speech (5% Sentence Intelligibility) as a Function of Distance Between Talker and Listener for Normal Voice Level

Table 9

Examples of Intruding Noises* Found in the Residential Outdoor Noise Environment in this Survey

Type of Source	Type of Neighborhood	Maximum Noise* Level dB(A)
4-Engine Turbofan Aircraft Landing	Noisy Urban Residential	100
Fire Engine Siren	Downtown City	95
Diesel Truck	Freeway Apartment	90
2-Engine Turbofan Aircraft Takeoff	Urban Residential	88
Street Sweeper	Urban Residential	87
Construction Crane	Downtown City	85
Construction Air Wrench	Downtown City	85
Train Passing	Urban City	84
Ready Mix Cement Truck	Downtown City	84
Motorcycle	Urban Residential	84
Rapid Transit Bus	Downtown City	84
Garbage Truck	Urban Residential	83
Freeway Automobile Traffic	Freeway Apartment	80
Automobile Horn	Urban Residential	78
Automobile Sports Car	Normal Suburban	78
Tire Squeal	Downtown City	78
4-Engine Turbofan Landing	Urban Residential	74
Automobile on Main Street	Small Town Residential	73
Ice Cream Truck with Music	Urban Residential	70
Private Aircraft Sight-Seeing	Grand Canyon	70
4-Engine Aircraft Overflight	Normal Suburban	70
Car Brake Squeal	Urban Residential	68
Helicopter Overflight	Urban Residential	68
Power Lawnmower	Urban Residential	68
People on Beach	Resort	65
Children Playing	Urban Residential	64
Lawn Edger	Small Town Residential	62
Cat Fight	Urban Residential	60
Dog Barking	Normal Suburban	60
Stationary Train with Engine Idling	Urban Residential	55
Automobile at Distance	Normal Suburban	55
Milk Truck	Normal Suburban	54
Rooster	Farm	54
Radio Playing Music	Urban Residential	52
Crickets in Evening and Night	Quiet Residential	50
Bird	Normal Suburban	45
Children Playing	Normal Suburban	44
Aircraft at High Altitude	Grand Canyon	40

* Note that these levels are as measured at the various locations and are not indicative of relative source noise.

of their spectra are given in Appendix B. The ranking of levels in Table 9 has no meaning with respect to the relative noise output of the various sources, since the measurements are essentially at random distances from the sources. The maximum noise levels for these events at the various locations range from 100 dB(A) for a 4-engined turbofan at an altitude of a few hundred feet distance during landing to 40 dB(A) for a similar aircraft probably at an altitude of 30,000 to 35,000 feet during cross-country cruise. They are illustrative of the great variety of the noises encountered in outdoor environments.

Obviously, many of these single event noises interfere with speech and other activities for brief intervals of time. However, their impact is not as easily quantified in terms of speech interference as were the constant level noise intrusions. One method for estimating the magnitude of the intrusion for single event noises is to ask people to rank the acceptability of a series of noises at differing levels. One of the most comprehensive recent studies of the subjective judgment of the noisiness of vehicle noise was conducted in England at the MIRA Proving Grounds.[28] The results are summarized in Figure 22. These results, obtained with relatively low residual noise levels, indicate that when the maximum noise level of the vehicle during its pass-by was less than 72 dB(A), it was judged quiet by the average observer. When the maximum noise level was between 72 and 82 dB(A), it was judged acceptable, and above 82 dB(A) it was judged noisy. These data are consistent with the apparent general acceptance of maximum levels in the range of 62 to 70 dB(A), which result from pass-bys on residential streets of standard passenger automobiles.

Although these results are useful in assessing the potential noisiness of an isolated single event, they do not necessarily account for the cumulative effect of multiple occurrences of single events. When a single event is of sufficient magnitude and duration, or repeated many times, it will add to the total noise energy in the hour, increasing the value of the equivalent noise level (L_{eq}). If the event is repeated often enough so that its total duration exceeds one percent of the hour, it will increase the value of L_1, and if its total duration exceeds 10 percent of the hour, it will increase

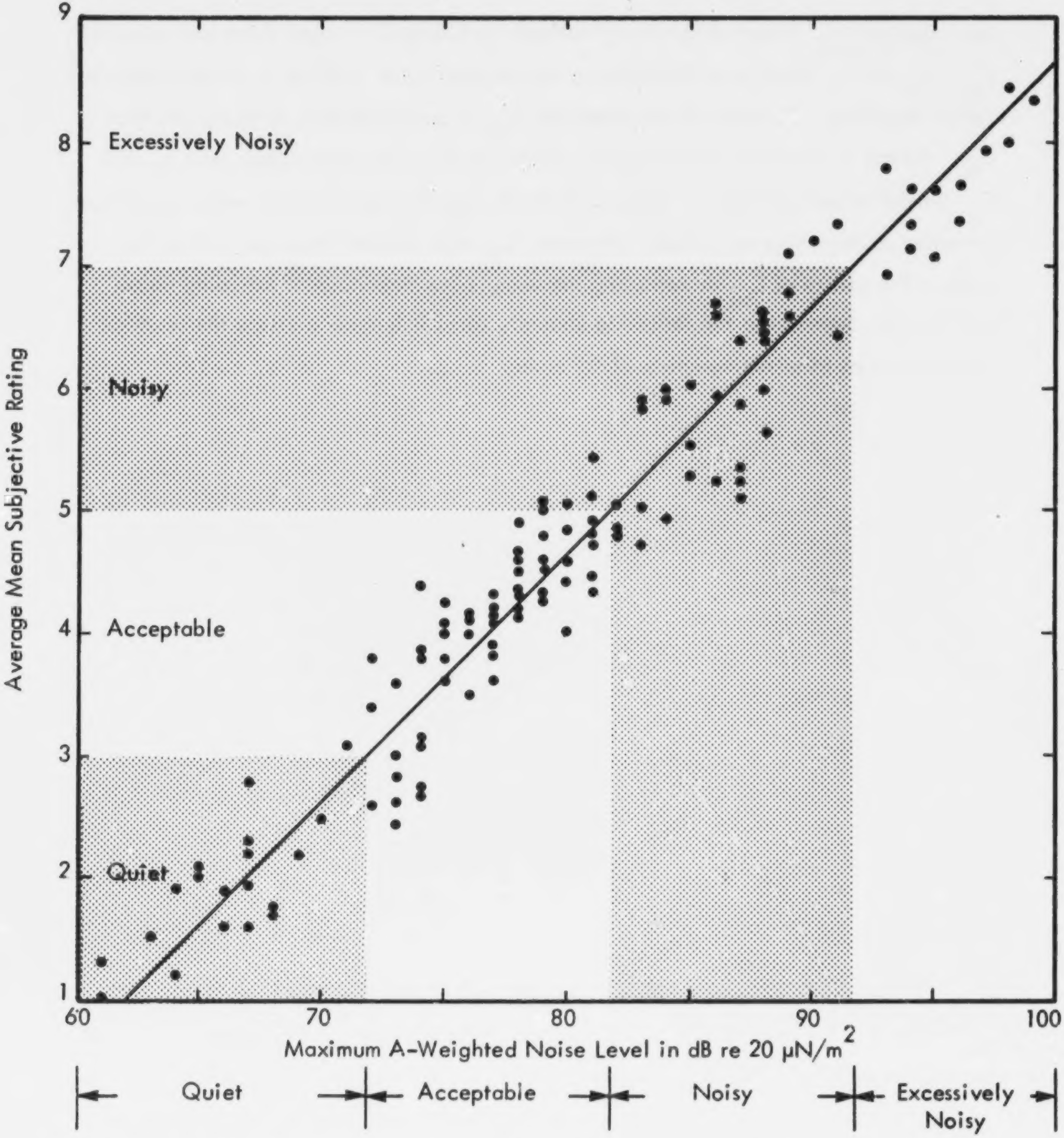


Figure 22. Average Mean Subjective Rating as a Function of Maximum Noise Level in dB(A) for the British Experiment at the Motor Industry Research Association Proving Grounds.[28] Nineteen Vehicles, Including Trucks, Automobiles and Motorcycles were Judged Twice in Each of Three Different Operating Modes by 57 Observers (Data Collapse and Figure from Galloway[29])

the value of L_{10}. These effects are illustrated in Figure 23, which shows the values of L_{eq}, L_{10} and L_1 relative to the value of the residual noise level for daytime at each of the 18 locations. For most of the locations, L_{10} is approximately 10 dB greater than L_{90}. At the 7 locations where significant intruding noises were noted, both L_1 and L_{eq} tended to be significantly higher relative to L_{90} than at locations where significant intruding sources were not noted. However, L_{10} only showed increases in 4 of the cases. The utility of L_{eq} in measuring the cumulative magnitude of intruding noises will become apparent in the following chapter, when it is used to relate the reaction of communities to intruding noises of all types.

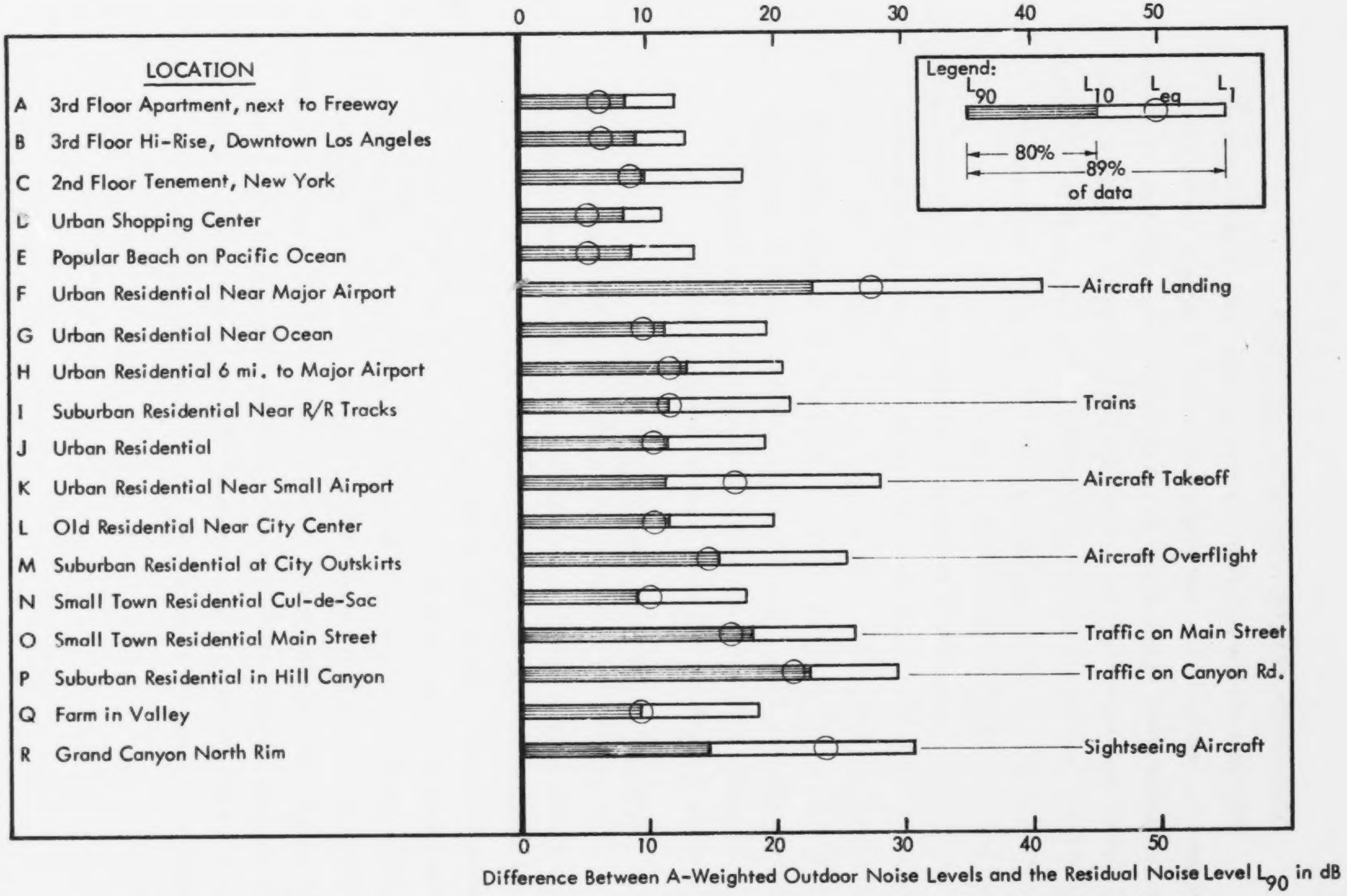


Figure 23. Relative Daytime Outdoor Noise Levels Found in 18 Locations Ranging from Wilderness to Downtown City with Significant Intruding Single Event Noise Sources Noted. Data are Arithmetic Averages of the Hourly Values in the Daytime Period (7:00 a.m. - 7:00 p.m.) of the Levels Which are Exceeded 10 Percent and 1 Percent of the Time (L_{10} and L_1, Respectively), and the Energy Average (L_{eq}), All Relative to the Residual Noise Level (L_{90})

5.0 COMMUNITY REACTION TO NOISE POLLUTION

Both types of noise pollution, the constant high level noise intrusion of the downtown city, and the intermittent single event noise intrusions in the suburban and urban residential areas, interfere with speech and other human activities. The downtown city type of noise environment has been recognized for centuries as undesirable for residential living. The single event type of noise intrusion has been experienced along railroad tracks for the last century and may be one of the reasons why land near railroads is not generally considered desirable for residential construction.

However, in the last 20 years, there has been a very large growth in both types of pollution due to the introduction of new types of noise sources into suburban and urban residential communities. These sources, such as jet aircraft, urban freeways, new industrial plants, and homeowner equipment, have created numerous community noise pollution problems. These problems have provided significant data and insight relating to community reaction and annoyance, and stimulated the development of several indices for measurement of the magnitude of intruding noises.

5.1 Correlation of Community Reaction with Noise

The advent of the commercial jet aircraft initially increased the maximum noise levels at some locations around major airports by 10 to 20 dB. These increases in noise caused widespread complaints and various forms of legal action from citizens living in neighborhoods located in the vicinity of several civil airports. This situation paralleled earlier history of military jet operations by the Air Force after World War II, although only a few Air Force operational bases were close to cities and towns. Unfortunately, the civil airports, which accounted for the majority of the early commercial jet operations, were located near the major cities which they served. Further, they were becoming surrounded by homes constructed in the post-war building boom. As jet operations and jet airports continued to grow in number, the airport noise problems tended to spread through wider areas of the community and to an ever-increasing number of communities.

The Air Force and other governmental agencies began to investigate the relationships between aircraft noise and its effect on people in communities in the early 1950's. This early research resulted in the proposal of a model by Rosenblith and Stevens[30] for relating aircraft noise intrusion and the probable community reaction. This model, first published by the Air Force, accounted for the following seven (7) factors:

- Magnitude of the noise with a frequency weighting for hearing response.
- Duration of the intruding noise (10 log relative duration).
- Time of year (windows open or closed).
- Time of day noise occurs.
- Outdoor noise level in community when the intruding noise is not present
- History of prior exposure to the noise source and attitude toward its owner.
- Existence of pure tone or impulsive character in the noise.

Corrections for these factors were generally made in 5 dB intervals since many of the initial relationships were based solely on the intuition of the authors, and it was considered difficult to assess the response to any greater degree of accuracy.[31-33] This method was incorporated in the first Air Force Land Use Planning Guide[34] in 1957, and was later simplified for ease of application by the Air Force and the FAA.

Many other methods have been proposed for describing the magnitude and duration of repeated single event type noise, with primary application to airport noise problems. Most of these methods represent an evolution of the community noise reaction model and consider at least some its principal factors. The factors considered by three of these methods for calculating the magnitude of noise intrusion are summarized in Table 10, and additional details of the calculation procedure are given in Appendix C.

The composite noise rating (CNR)[35] was introduced in the early 1960's and has been widely used by Federal agencies. The noise exposure forecast (NEF)[36] is

Table 10

Factors Considered in Each of Three Methods in Use for Describing the Intrusion of Aircraft Noise into the Community*

Factor	Composite Noise Rating (CNR)	Noise Exposure Forecast (NEF)	Community Noise Equivalent Level (CNEL)
Basic measure of single event noise magnitude	Maximum perceived noise level	Tone Corrected perceived noise level	A-weighted noise level
Measure of duration of individual single event	None	Energy integration	Energy integration
Time periods during day	Daytime (7 AM-10 PM) Nighttime (10 PM-7 AM)		Daytime (7 AM-7 PM) Evening (7 PM-10 PM) Nighttime (10 PM-7 AM)
Approximate weighting added to noise of single event which occurs in indicated period	Daytime 0 dB Nighttime 12 dB		Daytime 0 dB Evening 5 dB Nighttime 10 dB
Number (N) of identical events in time period	10 log N		10 log N
Summation of contributions	Logarithmic		Logarithmic

* See Appendix C for additional details.

a recent evolution of the CNR and is proposed as its successor by the FAA. It essentially updates the CNR by substitution of the tone and duration-corrected effective perceived noise level (EPNL) scale issued for aircraft certification,[13] in lieu of the perceived noise level (PNL) scale of the earlier CNR. Thus, the NEF accounts for both duration and pure tone content of each single event sound, whereas the CNR accounted for neither. The community noise equivalent level (CNEL)[37] was recently introduced by the State of California[38] for monitoring purposes. It is based on the A-weighting to avoid the complexity of the computer calculations required to obtain EPNL, and thus cannot contain a pure tone weighting. It also differs from the NEF by inclusion of the evening time period weighting, in addition to daytime and nighttime. However, despite these structural differences, the difference between the absolute values of CNEL and NEF for specific locations near airports is approximately constant at 35 ± 2 dB.

The CNEL has been applied to a series of community noise problems to relate the normalized measured CNEL with the observed community reaction. The normalization procedure followed the Rosenblith and Stevens method with a few minor modifications. The correction factors added to the measured CNEL to obtain the normalized CNEL are given in Table 11. Two examples of the application of these factors to the measured values of the equivalent noise levels (L_{eq}) of the intruding noise are given in Table 12. The examples are drawn from the results at two locations in the range survey, and illustrate an approximate procedure for calculating CNEL from the measured averages of L_{eq} in the daytime, evening and nighttime periods, accounting for both the period weightings of 0, 5 and 10 dB, respectively, and their durations relative to a 24-hour day.

Values of normalized CNEL have been calculated for 55 case histories from the literature and the files of Wyle Laboratories and Goodfriend-Ostergaard Associates. The distribution of the cases among the various sources which impact areas of the community are listed in Table 13 and the detailed data for each case are contained in Table 14. The results are summarized in Figure 24, with an approximate NEF and CNR scale shown for reference. The data are normalized to those descriptions in Table 11 for which the correction is zero.

Table 11

Corrections to be Added to the Measured Community Noise Equivalent Level (CNEL) to Obtain Normalized CNEL

Type of Correction	Description	Amount of Correction to be Added to Measured CNEL in dB
Seasonal Correction	Summer (or year-round operation)	0
	Winter only (or windows always closed)	-5
Correction for Outdoor Residual Noise Level	Quiet suburban or rural community (remote from large cities and from industrial activity and trucking)	+10
	Normal suburban community (not located near industrial activity)	+5
	Urban residential community (not immediately adjacent to heavily traveled roads and industrial areas)	0
	Noisy urban residential community (near relatively busy roads or industrial areas)	-5
	Very noisy urban residential community	-10
Correction for Previous Exposure & Community Attitudes	No prior experience with the intruding noise	+5
	Community has had some previous exposure to intruding noise but little effort is being made to control the noise. This correction may also be applied in a situation where the community has not been exposed to the noise previously, but the people are aware that bona fide efforts are being made to control the noise.	0
	Community has had considerable previous exposure to the intruding noise and the noise maker's relations with the community are good	-5
	Community aware that operation causing noise is very necessary and it will not continue indefinitely. This correction can be applied for an operation of limited duration and under emergency circumstances.	-10
Pure Tone or Impulse	No pure tone or impulsive character	0
	Pure tone or impulsive character present	+5

Table 12

Two Examples of Calculation of Normalized Community Noise Equivalent Level

Factor	Aircraft Landing Noise in Noisy Urban Residential Community(1)			Traffic Noise in Old Residential Area Near City Center(2)		
	Day	Eve.	Night	Day	Eve.	Night
Energy Equivalent Noise Level (Leq) in dB(A) for Time Period	80	83	75	56	57	53
Duration and Time of Day Correction Factor[3]	-3	-4	+6	-3	-4	+6
Subtotals Which are added Logarithmically to Obtain CNEL	77	79	81	53	53	59
Community Noise Equivalent Level	84			61		
Additional Corrections from Table 11:						
Seasonal	0			0		
Residual Noise Level	-5			0		
Experience & Attitude	0			-5		
Pure Tone or Impulse	5			0		
Total Additional Corrections	0			-5		
Normalized CNEL	84			56		
Actual Reaction	Extensive Lawsuits and Political Pressure			No Reaction		

(1) Location F in Figures 7 and 23

(2) Location L in Figures 7 and 23

(3) Duration correction is $\left(10 \log \frac{n}{24}\right)$ where n is the number of hours in the period.

Table 13

Number of Community Noise Reaction Cases as a Function of Noise Source Type and Reaction Category

	Community Reaction Categories			
Type of Source	Vigorous or Threats of Legal Action	Wide Spread Complaints	No Reaction or Sporadic Complaints	Total Cases
Transportation vehicles, including:				
Aircraft operations	6	2	4	12
Local traffic			3	3
Freeway	1			1
Rail		1		1
Auto race track	2			2
Total Transportation	9	3	7	19
Other single-event or intermittent operations, including circuit breaker testing, target shooting, rocket testing and body shop	5			
Steady state neighborhood sources, including transformer substations, residential air conditioning	1	4	2	7
Steady state industrial operations, including blowers, general manufacturing, chemical, oil refineries, et cetera	7	7	10	24
Total Cases	22	14	19	55

Table 14a

Summary of Data for 28 of the 55 Community Noise Reaction Cases

CASE NUMBER	NOISE SOURCE TYPE	CORRECTION FACTORS				NORMALIZED CNEL IN dB	NORMALIZED CNEL$_2$ IN dB	ADDITIONAL CORRECTION FACTORS		NORMALIZED NOISE LEVEL (PERIOD) IN dB	REFERENCE*
		SEASON	OUTDOOR RESIDUAL NOISE LEVEL	PRIOR EXPERIENCE & ATTITUDE	PURE TONE OR IMPULSE			TIME OF DAY	DURATION		
VIGOROUS REACTION											
A-1	Rocket Testing	0	10	0	5	78	78	0	-24	81	a
A-2	Wind Tunnel	0	5	5	0	80	82	10	0	83	c
A-3	Aircraft Landing	0	- 5	5	5	77	76	5	-21	81	a
A-4	Aircraft Takeoff	0	5	0	0	76	77	0	-16	76	a
A-5	Circuit Breaker Testing	0	0	0	5	78	78	0	-26	81	b
A-6	Auto Race Track	0	10	0	0	87	82	5	- 3	90	b
A-7	Aircraft Takeoff	0	5	5	5	84	83	5	-24	84	a
A-8	Aircraft Landing	0	- 5	0	5	84	86	10	-19	84	a
THREATS OF LEGAL ACTION											
B-1	Rocket Testing	0	10	0	5	72	72	0	-24	75	a
B-2	Aircraft Ground Runup	0	5	-5	0	72	72	0	-10	75	c
B-3	Wind Tunnel	0	5	0	5	71	73	10	0	74	c
B-4	Freeway	0	-10	0	0	76	77	10	0	76	a
B-5	Aircraft Overflight	0	5	5	5	73	72	5	-11	76	a
B-6	Plant Blower	0	0	5	5	77	78	10	0	80	b
B-7	Asphalt Quarry	0	10	0	0	74	74	0	0	77	b
B-8	Glass Bead Plant Blower	0	10	0	5	77	78	10	0	80	b
B-9	Plastics Plant	0	0	0	5	71	72	10	0	74	b
B-10	Target Shooting Range	0	10	5	5	74	74	0	- 3	77	b
B-11	Residential Air Conditioning	0	5	5	10	77	78	10	- 3	80	b
B-12	Unloading Newsprint	0	-10	0	5	71	72	10	0	75	b
B-13	Auto Body Shop	-5	0	5	5	75	75	0	- 7	79	a
B-14	Motorcycle Raceway	0	0	5	5	75	70	5	- 3	84	a
WIDESPREAD COMPLAINT											
C-1	Transformer Substation	0	10	0	5	64	65	10	0	67	a
C-2	Cement Plant	0	- 5	0	5	61	61	0	0	64	a
C-3	Aircraft Landing	0	- 5	5	5	67	66	5	-21	71	a
C-4	Paperboard Plant Cyclone	0	10	0	5	65	64	5	0	71	b
C-5	Oil Refinery	0	0	0	0	64	65	10	0	67	b
C-6	Milling & Grinding Metal	0	5	0	0	71	72	10	0	74	b

(a) Data from Wyle files.

(b) Data from L. S. Goodfriend.

(c) Data from "Handbook of Acoustic Noise Control, Volume II. Noise and Man," WADC Technical Report 52-204, Rosenblith, W.A., and Stevens, K.N., June 1953.

Table 14b

Summary of Data for 33 of the 55 Community Noise Reaction Cases

CASE NUMBER	NOISE SOURCE TYPE	CORRECTION FACTORS				NORMALIZED CNEL IN dB	NORMALIZED $CNEL_2$ IN dB	ADDITIONAL CORRECTION FACTORS		NORMALIZED NOISE LEVEL (PERIOD) IN dB	REFERENCE*
		SEASON	OUTDOOR RESIDUAL NOISE LEVEL	PRIOR EXPERIENCE & ATTITUDE	PURE TONE OR IMPULSE			TIME OF DAY	DURATION		
WIDESPREAD COMPLAINT ... continued											
C-7	Chemical Plant Material Handling	0	0	0	5	63	64	10	- 3	66	b
C-8	Residential Air Conditioning	0	5	5	5	71	72	10	0	74	b
C-9	Transformer Substation	0	5	0	5	72	73	10	0	75	b
C-10	Rail Car Shaker	0	0	0	5	62	62	0	- 6	65	b
C-11	Transformer Substation	0	10	0	5	67	68	10	0	70	b
C-12	Positive Displacement Blower	0	0	0	5	60	60	0	0	63	b
C-13	Aircraft Takeoff	0	5	-5	5	68	67	5	-24	68	a
C-14	Glass Manufacturing Plant	0	0	-5	0	62	63	10	0	65	b
SPORADIC COMPLAINTS											
D-1	Factory Air Pump	0	-10	0	0	61	61	0	0	64	c
D-2	Manufacturing Plant	-5	0	0	5	58	59	10	0	61	a
D-3	Chemical Plant	-5	5	0	0	56	57	10	0	59	a
D-4	Local Automobile Traffic	0	10	-5	0	61	61	0	-11	64	a
D-5	Plastics Plant	0	10	0	0	61	62	10	0	64	b
D-6	Power Station	0	- 5	-5	0	59	60	10	0	62	b
NO OBSERVED REACTIC											
E-1	Transformer Substation	0	10	-5	5	50	51	10	0	53	a
E-2	Aircraft Runup	0	5	0	0	51	51	0	- 5	54	c
E-3	Asphalt Tile Shaker	0	- 5	0	0	54	55	10	- 1	57	a
E-4	Asphalt Tile Reddler	0	0	0	10	50	51	10	-10	53	a
E-5	Power Plant	0	10	0	0	57	58	10	0	60	b
E-6	Aircraft Overflight	0	5	-5	5	58	57	0	-15	59	a
E-7	Aircraft Landing	0	0	-5	5	60	61	10	-17	63	a
E-8	City Traffic	0	0	-5	0	51	50	5	-18	56	a
E-9	Aircraft Lag and Takeoff	0	0	0	0	57	56	5	-17	61	a
E-10	Local Traffic	0	0	-5	0	54	54	0	-24	50	a
E-11	Auto Assembly Plant	0	0	-5	0	61	62	10	0	64	b
E-12	Can Manufacturing	0	-5	-5	0	57	58	10	0	50	b
E-13	Oil Refinery	0	-5	-5	0	59	60	10	0	62	b

(a) Data from Wyle files.

(b) Data from L. S. Goodfriend.

(c) Data from "Handbook of Acoustic Noise Control, Volume II. Noise and Man," WADC Technical Report 52-204, Rosenblith, W.A., and Stevens, K. N., June 1953.

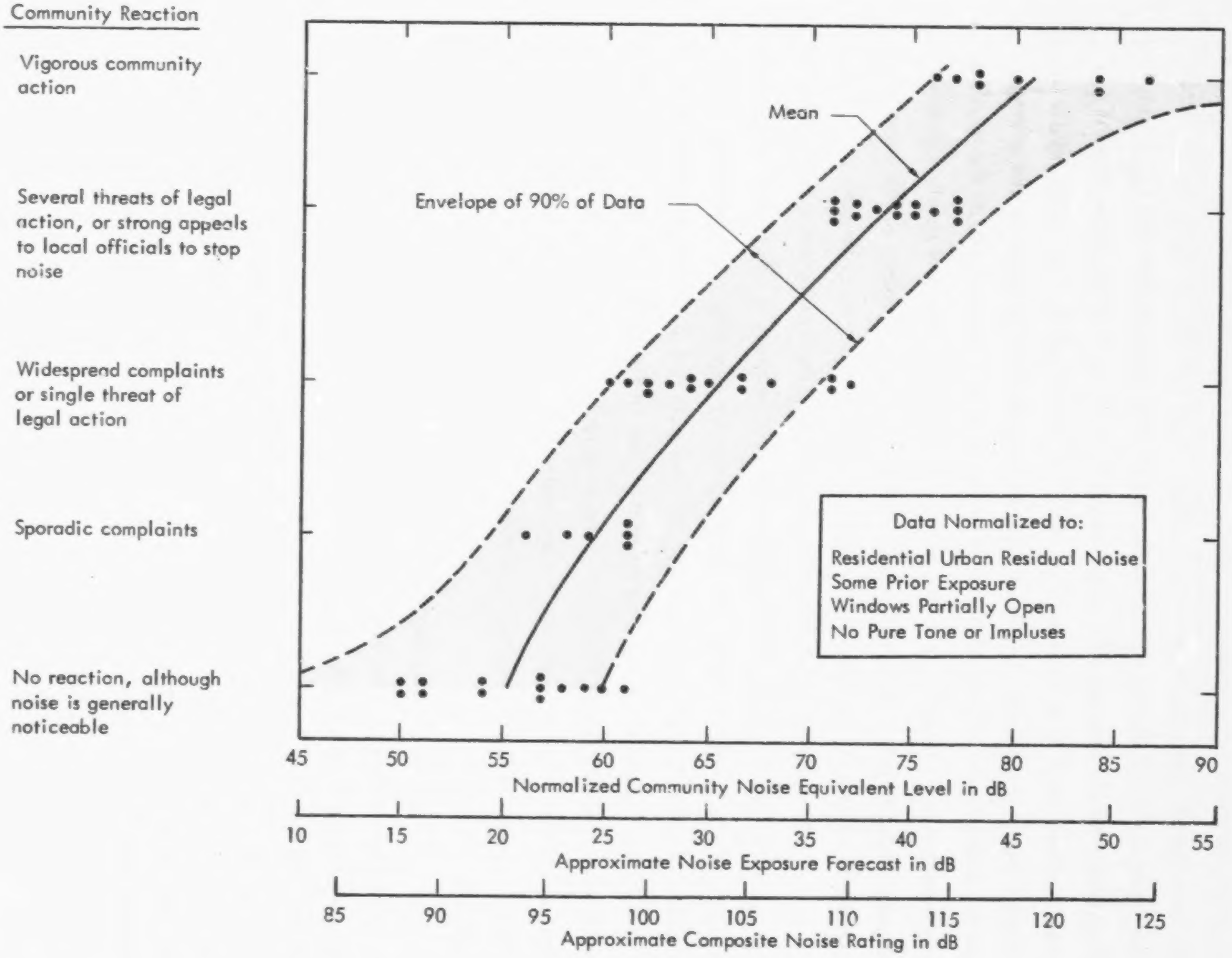


Figure 24. Community Reaction to Intrusive Noises of Many Types as a Function of the Normalized Community Noise Equivalent Level

The "no reaction" response in Figure 24 corresponds to a level which ranges between 50 and 61 dB with a mean of 55 dB. This mean value is approximately 7 dB above the mean value assumed in categorizing the daytime residual noise (L_{90}) level for a "residential urban" community, which is the baseline category for the data in the figure. This difference of 7 dB between the mean reaction line and L_{90} is only 2 dB greater than the average difference between the outdoor median noise level (L_{50}) and the residual noise level, as shown in Table 3. Consequently, from these results it appears that no community reaction to an intruding noise is expected on the average when the normalized CNEL of the intruding noise is approximately equal to the daytime outdoor median noise level (L_{50}). This conclusion is not surprising; it simply suggests that people tend to judge the magnitude of an intrusion with reference to the noise environment which exists without the presence of the intruding noise source.

The data in Figure 24 indicate that widespread complaints may be expected when the normalized value of CNEL exceeds the outdoor residual noise level by approximately 17 dB, and vigorous community reaction may be expected when the excess approaches 33 dB. The standard deviation of these data is 3.3 dB and an envelope of ±5 dB encloses approximately 90 percent of the cases in Figure 24. Hence, this relationship between the normalized CNEL and community reaction appears to be a reasonably accurate and useful tool in assessing the probable reaction of a community to an intruding noise and in obtaining one type of measure of the impact of an intruding noise on a community.

These community reaction data have also been used to test the effect of the various normalizing factors in Table 11, together with the duration and time period weighting factors in the CNEL, on the degree of correlation between the community reaction and the normalized CNEL. The results, in Table 15, show that the duration is the factor most necessary in the normalization to bring the data closer to a common line and thus minimize the standard deviation. The absence of a duration correction increases the standard deviation from 3.3 to 8.1 dB and would result in extending the bounding envelope from ±5 dB, as on the figure, to approximately ±12.4 dB. The next most

Table 15

Effect of Normalizing Factors on 55 Community Noise Reaction Cases as Measured by the Standard Deviation of the Data About the Mean Relationship Between Community Reaction and Normalized CNEL

Factors* Included in Normalizing Measured Noise Level	Number of Cases with Nonzero Correction in Deleted Factor(s)	Standard Deviation in dB of all Cases Except those Which have Vigorous Reaction or no Reaction	Standard Deviation of all 55 Cases
All	–	2.9	3.3
All, except duration	28	7.5	8.1
Only duration and time of day correction in the measured CNEL	1	7.1	7.5
All, except residual noise level	35	6.2	6.4
All, except time of day	38	4.6	4.6
All, except pure tone and impulse	32	3.7	4.3
All, except experience and attitude	23	3.4	4.0
All, except seasonal	3	2.9	3.3

* Factors are from Tables 10 and 11

important factor is the residual noise level correction, lack of which increases the standard deviation from 3.3 to 6.4 dB, a factor of almost two. Less important, but still significant, are the corrections for time of day, pure tone/impulse, and prior experience/ attitude, the lack of which resulted in standard deviations of 4.6, 4.3 and 4.0, respectively. No change occurred by removing the seasonal factor which was only applied in three of the 55 cases.

The original Rosenblith and Stevens method computed the magnitude of the noise by a quantity essentially proportional to L_{eq} for the time period during which community reaction was caused. Thus, for a complaint against daytime noise, the reaction would be compared against normalized L_{eq} for daytime, whereas for a nighttime noise, the reaction would be compared against the normalized L_{eq} for the nighttime including the +10 dB nighttime weighting factor. This procedure is slightly different from that used in the CNEL which accounts for the contributions of all three periods in a single number.

For comparison, the 55 cases have been plotted in Figure 25 using the original procedure,[30] except that the A-weighted equivalent level is used for the magnitude of the noise. The results are generally similar to those of Figure 24, although the standard deviation is 3.5 dB rather than 3.3 dB.

The data for the 55 cases were also compared with $CNEL_2$ (see Appendix C) which was obtained by replacing the day-evening-night corrections of the standard CNEL with the day-night corrections of the NEF calculation procedure. The resulting mean line was altered by less than 1 dB from that given in Figure 24 and the standard deviation was only 0.1 dB greater than before, an insignificant difference. Thus, these 55 cases can support either type of time period weighting for a single-number measure of noise (CNEL or $CNEL_2$) over a 24-hour period, or the original period comparison concept, all in combination with the energy equivalent A-weighted noise level and the other correction factors in Table 11, for the prediction of community reaction to noise pollution.

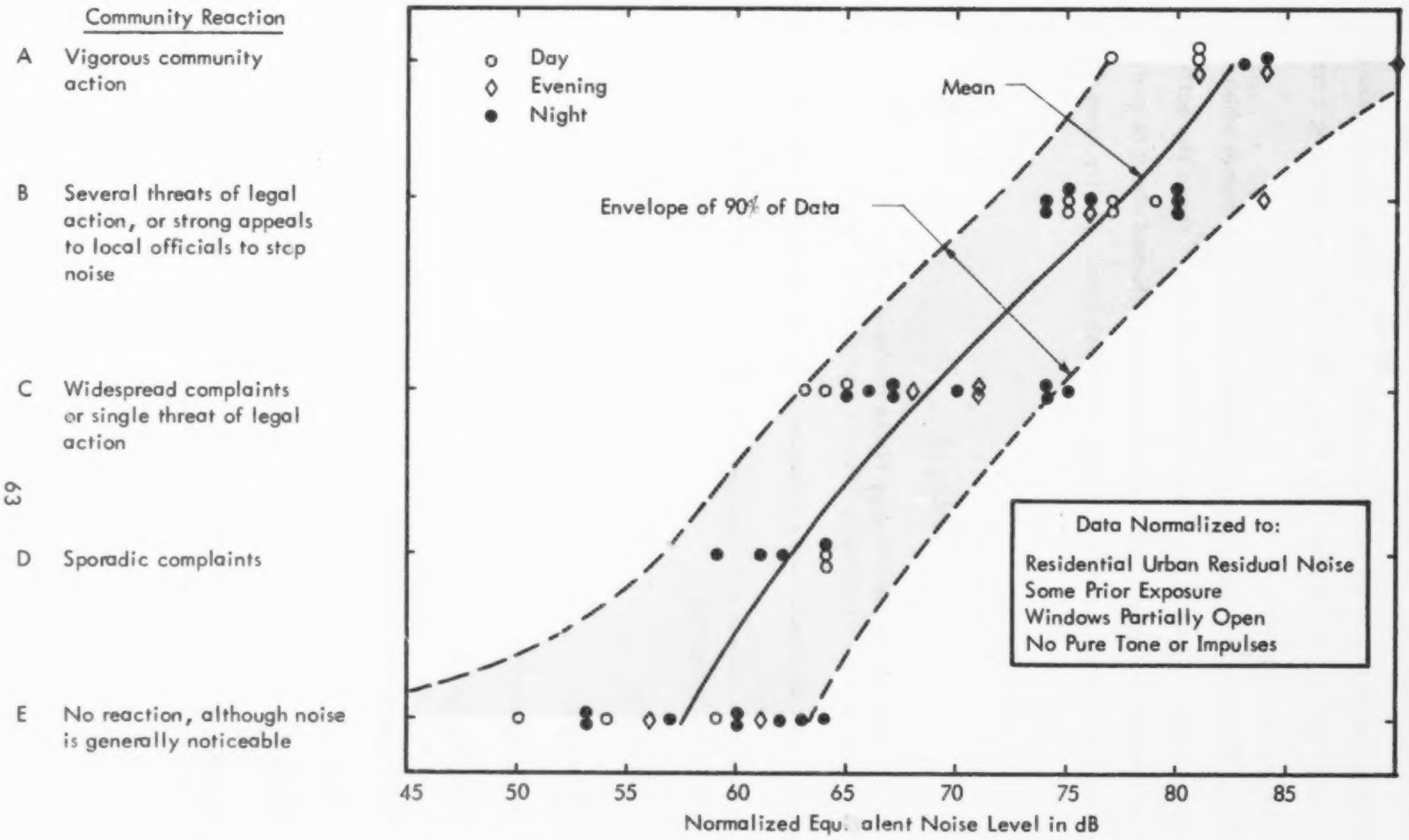


Figure 25. Community Reaction to Intrusive Noises of Many Types as a Function of the Normalized Noise Level Using Original Procedures of Rosenblith and Stevens

5.2 Community Reaction and Annoyance

The normalized CNEL scale can also be compared with the results of social surveys, such as those taken in London and in the USA.[39-42] These surveys determine community attitude by asking people what they think, rather than by assessing overt reaction, as in the previous section.

Figure 26 shows that people are preponderantly in their homes when they are annoyed by noise. Table 16, from an American survey,[40] shows the activities disturbed as reported by people who were "extremely disturbed about aircraft noise." As might be anticipated, problems related to speech intelligibility head the list.

Table 16

Activities Disturbed by Noise as Reported by
People who are "Extremely Disturbed by Aircraft Noise"

Activity	Percent
TV/Radio reception	20.6
Conversation	14.5
Telephone	13.8
Relaxing outside	12.5
Relaxing inside	10.7
Listening to records/tapes	9.1
Sleep	7.7
Reading	6.3
Eating	3.5

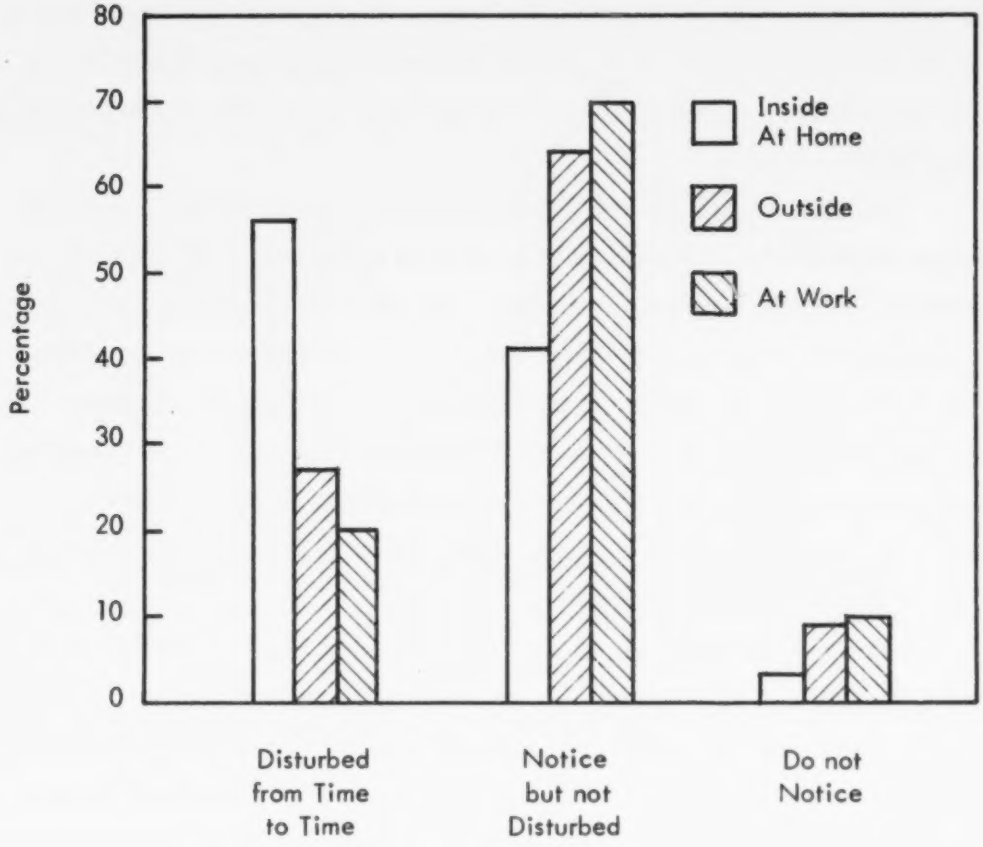


Figure 26. Percentage of People Who Were Ever Disturbed by Noise at Home, Outdoors and at Work in London City Survey[20]

Figure 27 shows the average annoyance reaction found in the London Airport Survey[39] as a function of CNR[36] and approximate normalized CNEL. Figures 28 and 29 show the relationships of those who are "very much annoyed" and those "only a little, or not annoyed" with data from the same survey. Also shown in Figure 28 is a data point from a survey in Sweden,[43] and a tangent line through the most important range of community reaction.

These results demonstrate that a majority of the citizens are clearly very much annoyed when the noise is sufficient to produce a normalized CNEL of 81 dB, which would be expected to produce a vigorous community reaction in accordance with the data in Figure 24. They also show that a small but significant percentage of the population is still very much annoyed at the CNEL 55 value, where no community reaction is expected. Thus, the true impact of the polluting effects of intrusive noises as measured by annoyance goes deeper than indicated by the "no reaction" point.

5.3 Applicability of Noise Pollution Level and Traffic Noise Index to Community Noise Assessment

Although the various versions of the community reaction correlation procedure have found favor in this country and in international standardization,[12,47] there are continuing efforts to develop new and better noise scales. Two of the most recent efforts stemmed from a traffic noise and social survey by Griffiths and Langdon[22] in England in 1968. They assessed the dissatisfaction of residents at 11 sites with traffic noise, and related the results to measured values of the noise. These measurements were reported in terms of L_{10}, L_{50} and L_{90}; L_{eq} values were reported later by Robinson.[44] The statistical values reported were the arithmetic averages of 24 samples (one per hour) of 100 seconds duration each.

Griffiths and Langdon devised a traffic noise index which appeared to give the best correlation between their 24-hour averages and the dissatisfaction scores. This index is defined as:

$$TNI = L_{90} + 4 \ (L_{10} - L_{90}) \ - \ 30 \text{ in dB} \qquad (5\text{-}1)$$

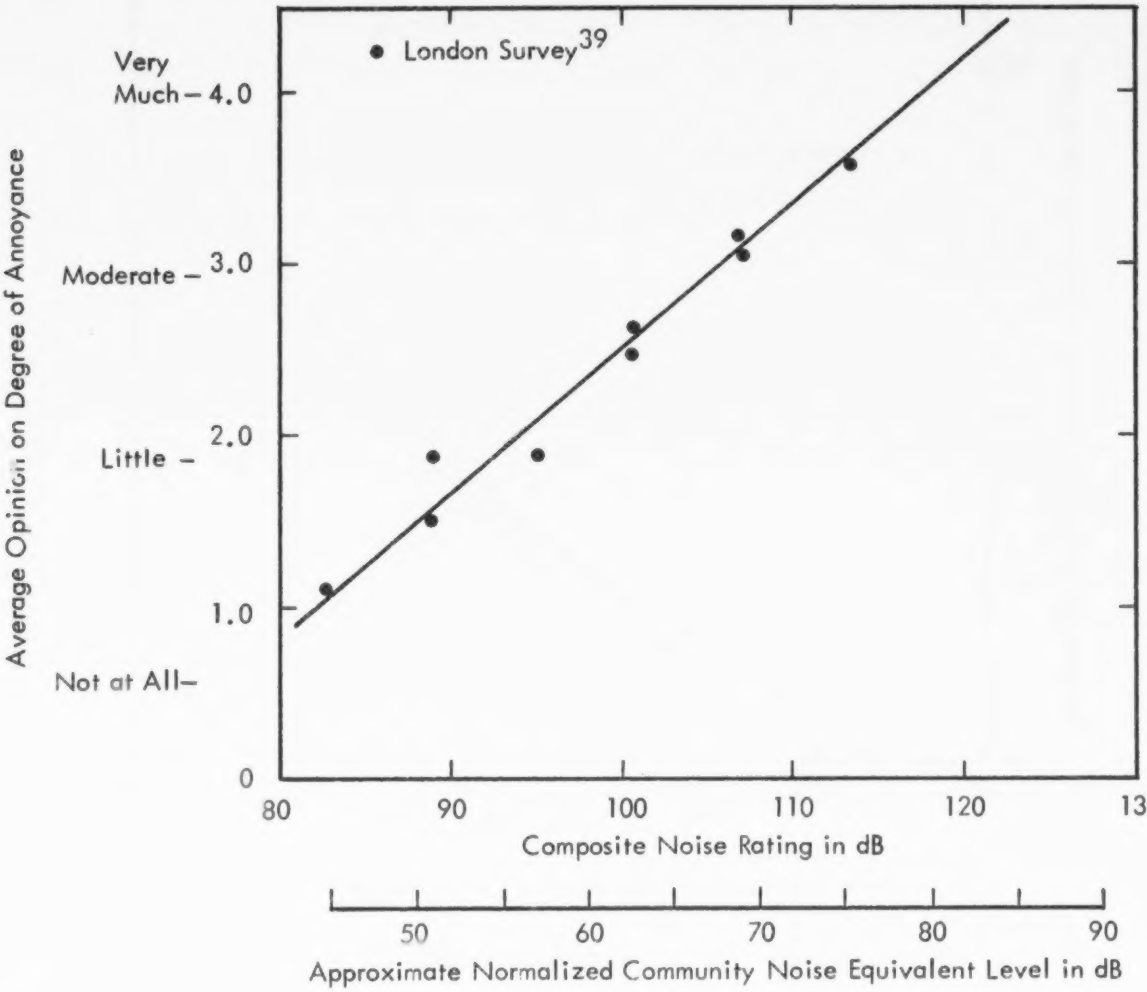


Figure 27. Relationship Between Average Expression of Annoyance to Aircraft Noise and the Composite Noise Rating, and with the Approximate Scale for the Normalized Community Noise Equivalent Level (After Galloway[36])

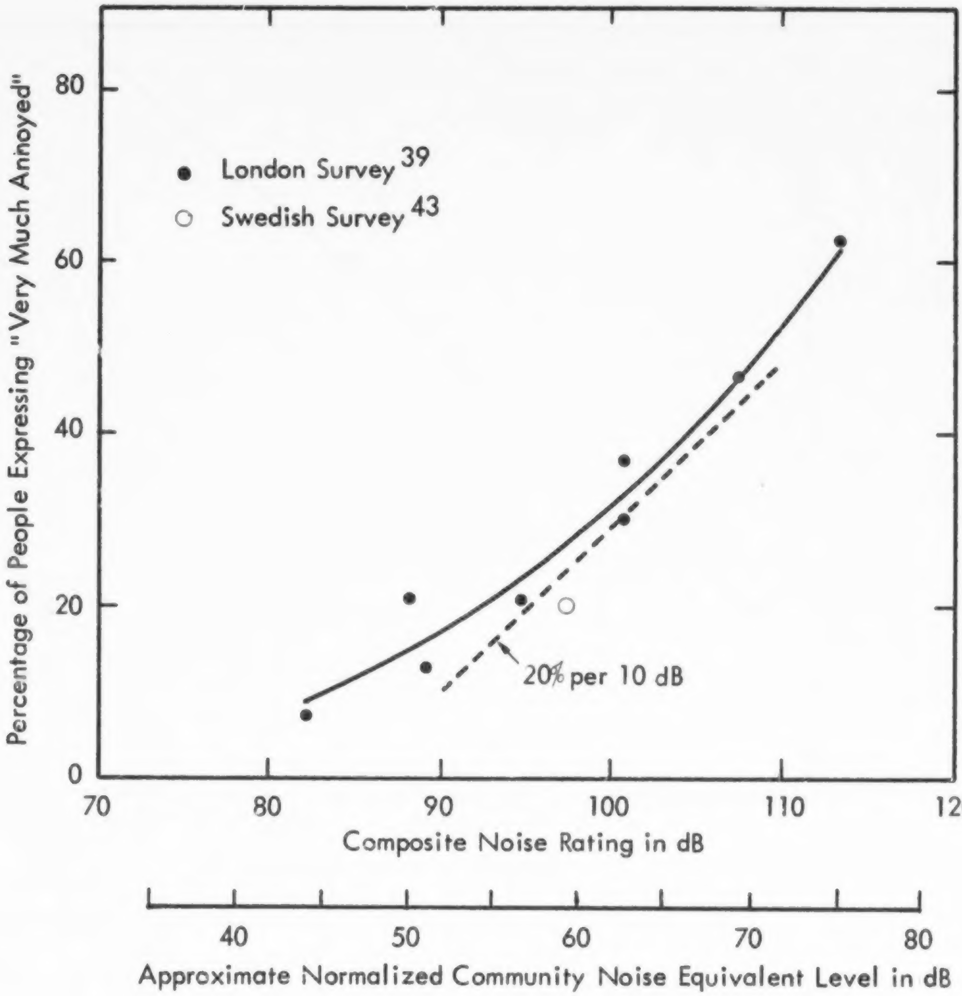


Figure 28. Percentage of People Expressing "Very Much Annoyed" as a Function of Composite Noise Rating and with the Approximate Scale for the Normalized Community Noise Equivalent Level

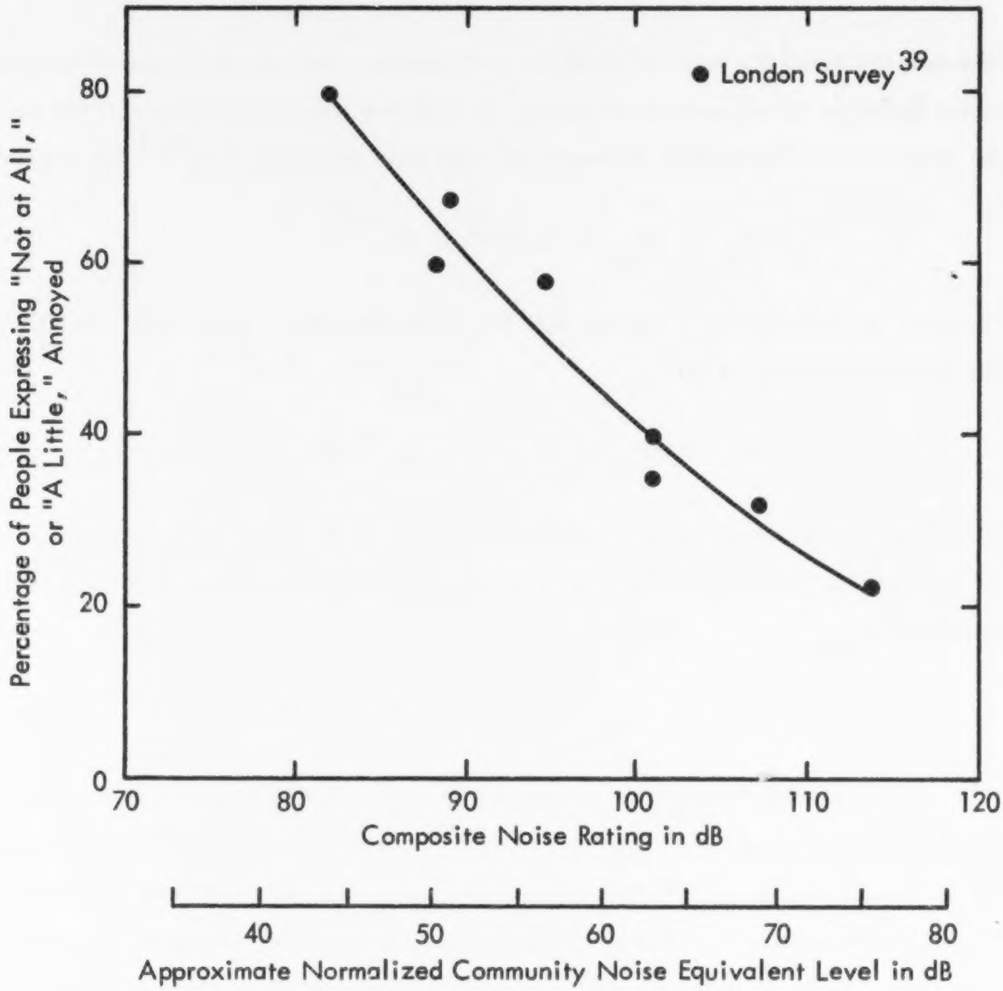


Figure 29. Percentage of People Expressing "Not At All" or "A Little" Annoyed as a Function of Composite Noise Rating and with the Approximate Scale for the Normalized Community Noise Equivalent Level

Robinson reviewed the work of Griffiths and Langdon and proposed a quantity called Noise Pollution Level, which accounted for both the equivalent energy of the noise and the amount of its fluctuation in terms of its standard deviation (σ).[44,45] His primary definition is:

$$NPL_e = L_{eq} + 2.56\sigma \text{ in dB} \qquad (5\text{-}2)$$

However, in deriving the constants for NPL_e from the traffic noise study, he utilized the approximate form of NPL:

$$NPL' = L_{eq} + (L_{10} - L_{90}) \text{ in dB} \qquad (5\text{-}3)$$

In addition, he proposed several other approximations which could be applied in appropriate situations, including the following expression which does not require direct computation of L_{eq}:

$$NPL_a = L_{50} + 2.56\sigma + \sigma^2/8.68 \text{ in dB} \qquad (5\text{-}4)$$

Figure 30 compares TNI and NPL_e, calculated from the 24 average values of 100-second samples, with the dissatisfaction scores at the 11 Griffiths and Langdon sites. The correlation coefficient and standard deviation are approximately 0.88 and 3.9 dB, respectively, for TNI, and 0.82 and 3.2 dB for NPL_e. Figure 31 compares L_{eq} and $(L_{eq} - L_{90})$ for these same data. This measure of $(L_{eq} - L_{90})$ is similar to the measures used in the correlation of community reaction in Figures 24 and 25. The correlation coefficient and standard deviation are approximately 0.63 and 5.8 dB, respectively, for L_{eq}, and 0.76 and 1.9 dB for $(L_{eq} - L_{90})$.

There are three principal observations which can be made from these comparisons. First, all measures except L_{eq} (only) show reasonable correlation with the trend of the data, with TNI the best and NPL_e second best.

Second, the standard deviations for $(L_{eq} - L_{90})$ are much smaller than those for TNI and NPL_e. This difference is the result of the difference in the decibel ranges of the three scales, approximately 29 dB for TNI, 18.5 dB for NPL_e and 7.5 dB for $(L_{eq} - L_{90})$.

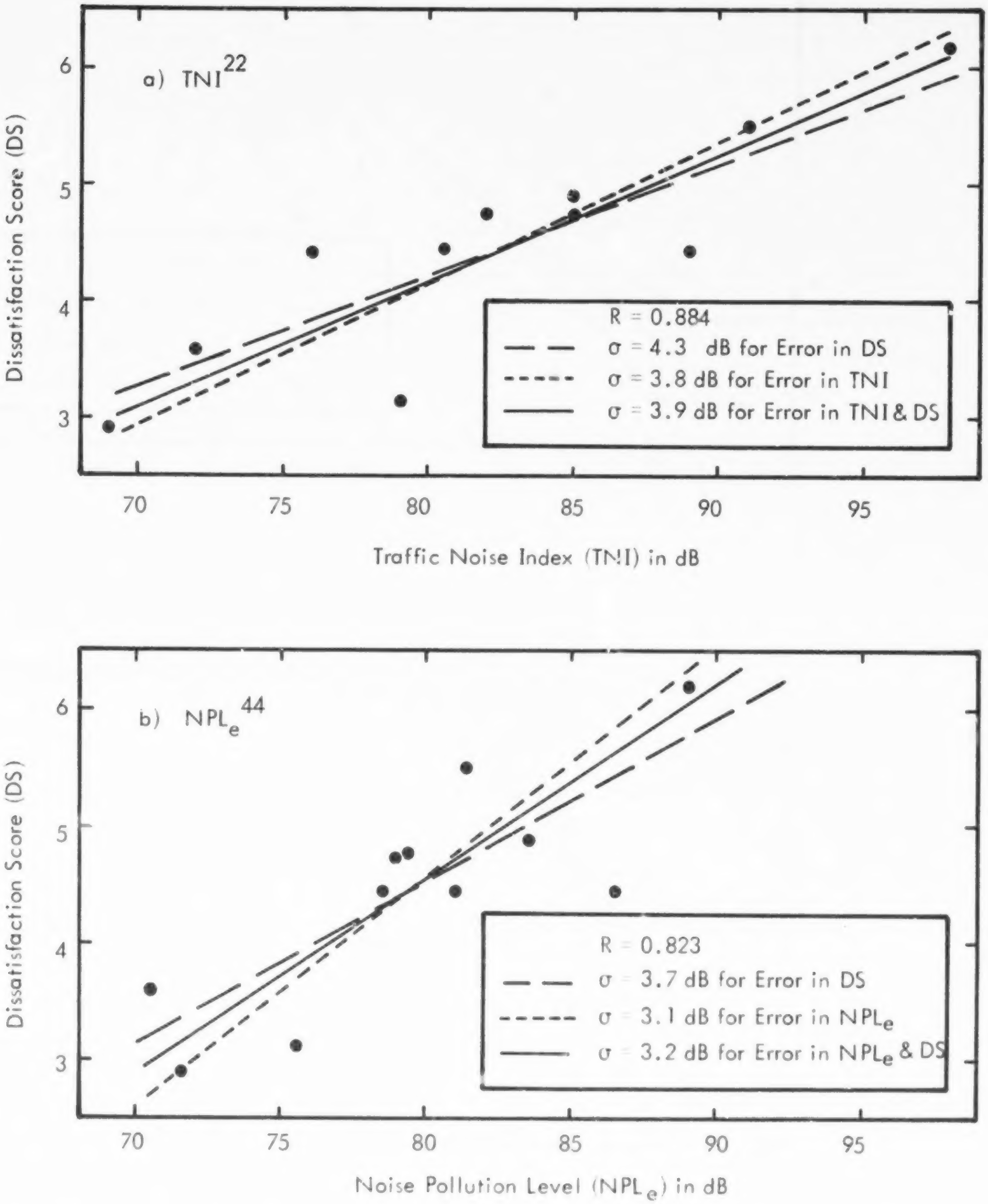


Figure 30. Comparison of Griffiths and Langdon Dissatisfaction Score Data with (a) Traffic Noise Index and (b) Noise Pollution Level. Regression Lines and Their Associated Standard Deviations in Decibels are based on Assuming all Error is in the Dissatisfaction Score, Assuming all Error in the Index, or Level, and Assuming Error is in both Measures

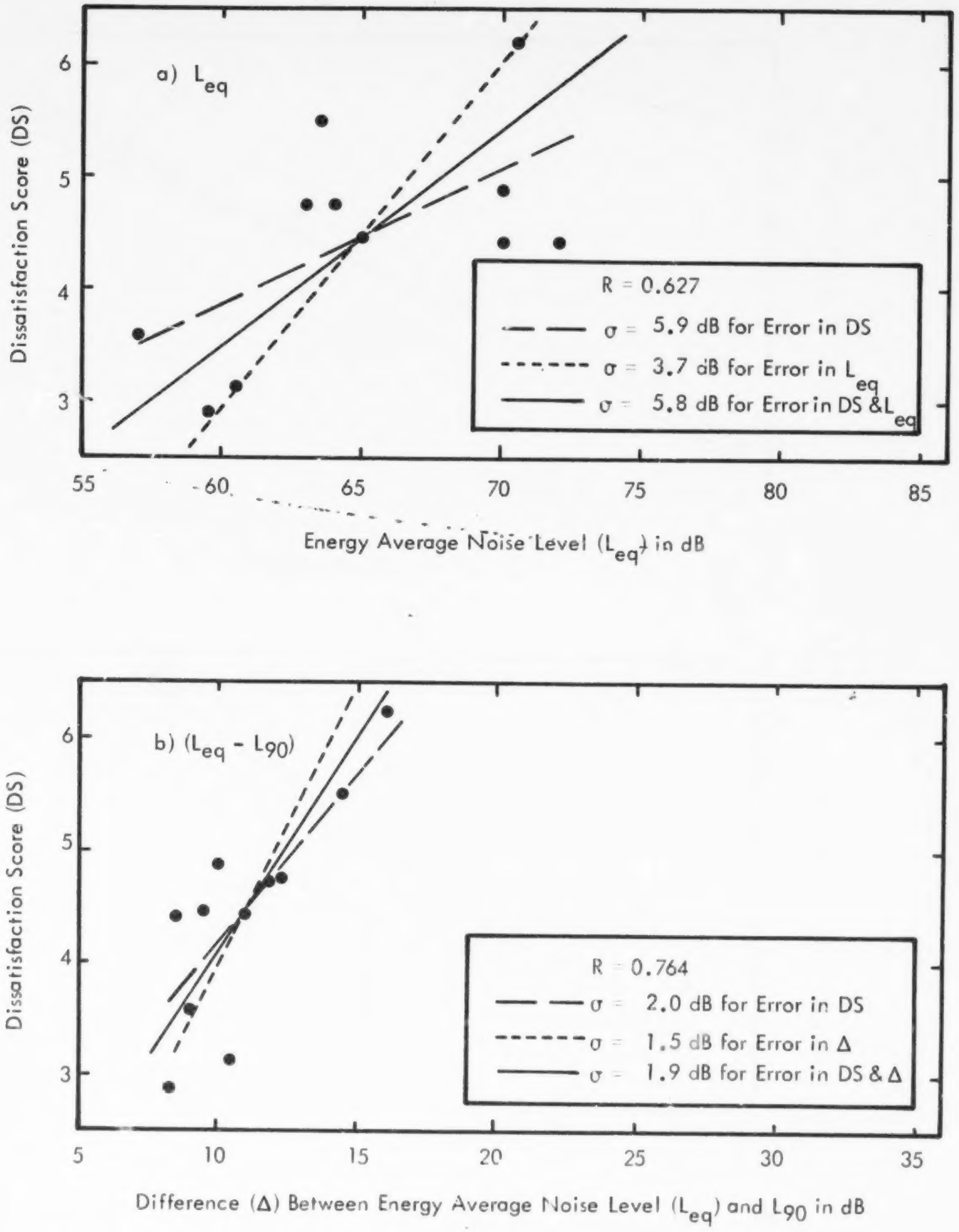


Figure 31. Comparison of Griffiths and Langdon Dissatisfaction Score Data[20] with (a) Energy Average Noise Level and (b) Difference Between Energy Average Noise Level and L_{90}. Regression Lines and Their Associated Standard Deviations in Decibels are Based on Assuming all Error is in the Dissatisfaction Score, Assuming All Error in the Level, and Assuming Error is in both Measures.

Third, the dynamic range of the basic L_{eq} data is relatively small, approximately 15 dB. Considering that the basic noise data were acquired in 100-second samples, some random error, probably of the order of ±2 dB, may be expected in the estimates of both L_{eq} and L_{10} at the various sites. (For example, see Table 8 in Section 3.2.) In addition, the day-night variation may differ between the sites, as seen in Figures 10 through 12, adding additional variability to the comparisons. Further, there was undoubtedly some variation in level throughout the neighborhood at each site. These probable errors in the measurement, plus the inherent errors in assessing the actual dissatisfaction scores, are at least of the magnitude of the errors exhibited in the correlations of the various scales. Therefore, it is difficult to conclude from these data that any one of these three candidate scales is to be preferred.

The TNI and NPL were computed at each of the 18 locations in the noise survey undertaken for this report. An example of the results is shown for the daytime period in Figure 32, together with L_{eq} and L_{10}, with all values plotted relative to L_{90}. For many of the locations, TNI is numerically similar to L_{eq}, within approximately ±6 dB. However, at a few locations where intruding single event noises were sufficiently numerous to effect L_{10}, the TNI is much greater than L_{eq}, with a maximum difference of almost 40 dB. In all cases, the NPL_e is greater than L_{eq}, as would be expected from Equation (5-2). The differences ($NPL_e - L_{eq}$) range between approximately 6 and 26 dB.

These data were also used to calculate the numerical differences among the three methods for calculating NPL, which were given in Equations (5-2) through (5-4). The results for the 18 locations are summarized in Table 17. The mean differences and standard deviations for daytime are 3.8 and 3.7 dB, respectively, for ($NPL_e - NPL_a$) and 1.4 and 1.3 dB, respectively, for (NPL_e - NPL'). In all periods, the standard deviation using NPL' was less than that obtained using NPL_a, indicating that it is a more consistent estimator of NPL_e.

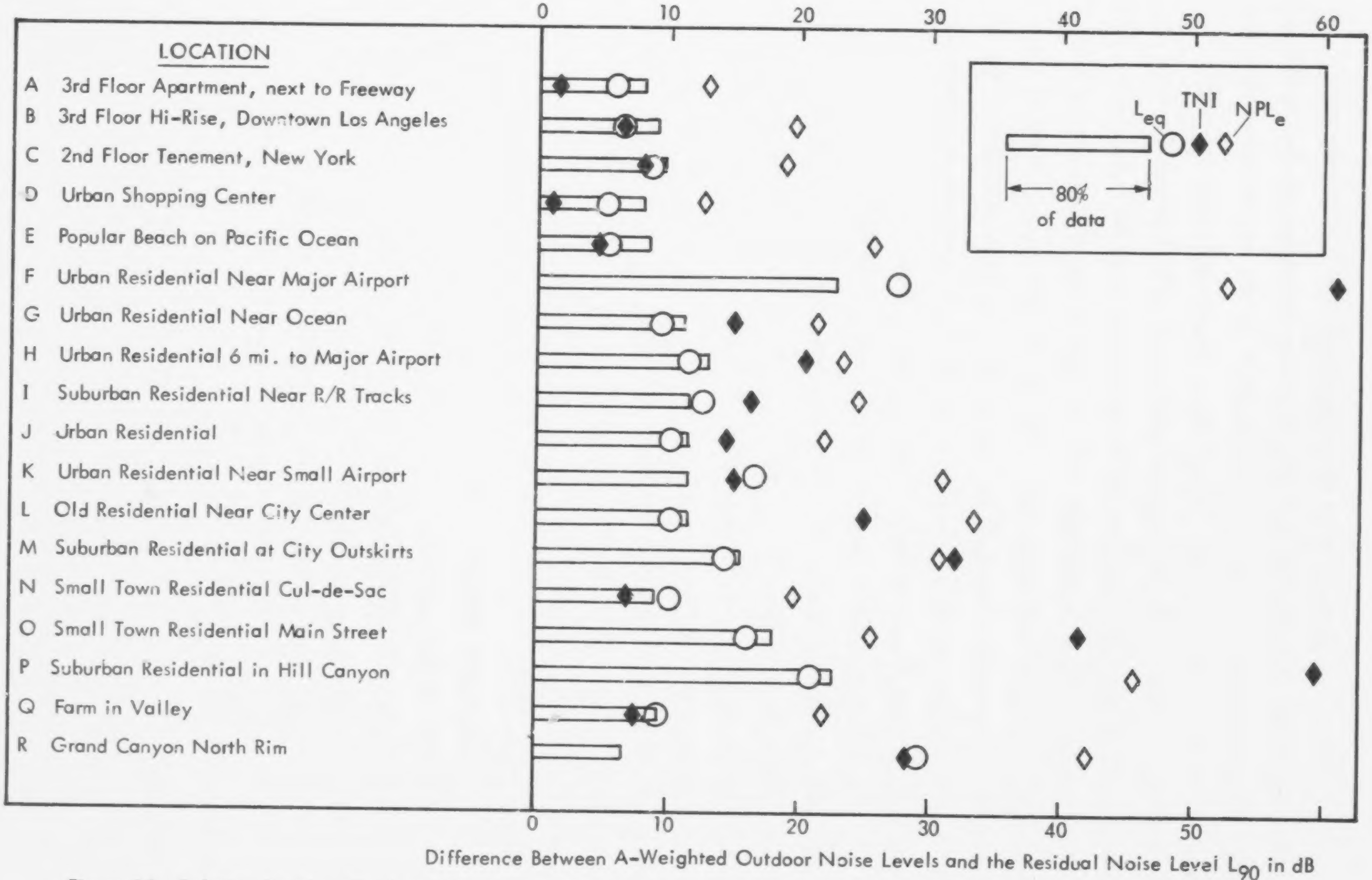


Figure 32. Relative Daytime Outdoor Noise Levels Found in 18 Locations Ranging from Wilderness to Downtown City with Significant Intruding Single Event Noise Sources Noted. Data are Arithmetic Averages of the Hourly Values in the Daytime Period (7:00 a.m. - 7:00 p.m.) of the Levels Which are Exceeded 10 Percent of the Time (L_{10}), and the Energy Average (L_{eq}), the Traffic Noise Index (TNI) and the Noise Pollution Level (NPL_e), all Relative to the Residual Noise Level (L_{90})

Table 17

Relationships Among Various Methods of Calculating Noise Pollution Level for Data from 18 Locations

Location	$NPL_e^* - NPL_a^*$				$NPL_e - NPL'^*$			
	Day	Eve	Night	24 Hours	Day	Eve	Night	24 Hours
A	1.2	1.3	-1.6	-0.7	-0.7	-0.7	4.0	3.8
B	-0.1	1.8	3.0	2.2	2.5	-0.7	1.0	6.5
C	1.8	1.7	1.2	1.7	0.9	0.8	0.1	1.7
D	1.2	0.7	2.2	-1.2	-0.4	0.5	2.4	6.2
E	1.5	1.8	1.6	1.3	0.4	-0.1	-0.3	1.6
F	10.3	10.6	15.6	10.5	2.3	3.5	7.8	7.4
G	2.8	2.1	1.5	1.7	3.2	0.5	1.9	6.8
H	2.3	1.7	3.3	1.8	0.4	0.7	1.4	2.8
I	3.5	4.1	4.2	1.6	1.2	1.9	9.7	7.0
J	3.2	1.8	4.0	3.1	0.7	0.8	3.4	3.1
K	9.5	7.4	8.7	7.1	2.9	2.4	3.8	7.9
L	2.7	3.3	2.5	3.7	1.2	0.9	4.0	2.7
M	4.4	8.8	5.8	3.7	0	1.7	7.0	6.9
N	4.2	2.7	2.5	2.9	0.7	0.8	2.3	3.7
O	1.4	2.0	6.1	4.0	1.9	0.3	2.8	5.6
P	1.2	0.4	-1.7	0.2	1.0	2.6	9.9	5.2
Q	2.5	1.8	13.7	5.1	3.4	0.2	4.2	3.7
R	14.4	0	2.9	4.2	3.7	2.7	3.6	0.4
Mean Difference	3.8	3.0	4.2	2.9	1.4	0.9	3.8	4.6
Standard Deviation	3.7	2.9	4.4	2.7	1.3	1.2	2.9	2.2

$$* \left\{ \begin{array}{l} NPL_e = L_{eq} + 2.56\,\sigma \\ NPL_a = L_{50} + 2.56\,\sigma + \sigma^2/8.68 \\ NPL' = L_{eq} + L_{10} - L_{90} \end{array} \right.$$

Thus, NPL_e can be reasonably estimated for a wide variety of real outdoor noise environments by NPL'. This simplified approximation can be written as:

$$NPL' = (L_{eq} - L_{90}) + L_{10}$$

or (5-5)

$$(NPL' - L_{90}) = (L_{eq} - L_{90}) + (L_{10} - L_{90})$$

The computation for the daytime estimates of $(NPL' - L_{90})$ can be visually made for the data of Figure 32 by adding the $(L_{10} - L_{90})$ bar to the value of $(L_{eq} - L_{90})$. The implication of this simplification is that NPL tends to count the magnitude of the intruding noise twice – first in its contribution to L_{eq} and second in its contribution to L_{10}. Thus, it might be expected that a correlation of community reaction, such as that given for the 55 cases in Figures 24 and 25, would exhibit a wider data scatter than obtained with $(CNEL - L_{90})$, or $(L_{eq} - L_{90})$.

An example of such an application of NPL was calculated for aircraft flights over residential areas with differing residual noise levels. In all cases, the aircraft noise was assumed to have a maximum level of 90 dB(A) and an effective (energy equivalent) duration of 5 seconds. The aircraft noise-time history was assumed to be triangular. The community reaction for each case was estimated from Figure 24. The results of this example are given in Figure 33. The left-hand side of the envelope of cases is determined by the condition of 1 flight per hour. It shows no correlation between NPL and community reaction, since the NPL varied only slightly although $(L_{eq} - L_{90})$ varied significantly. The right-hand side of the envelope results from the condition of 30 flights per hour. Here, the NPL varied significantly with the reaction scale. From this example, one might conclude that it would be difficult to obtain good correlation between reaction and NPL, whenever the duration of the intruding noise is only a small fraction of a given time period. Better correlation may be obtained when more than one type of source is present;[46] however in this case the results are based on estimated rather than measured noise levels.

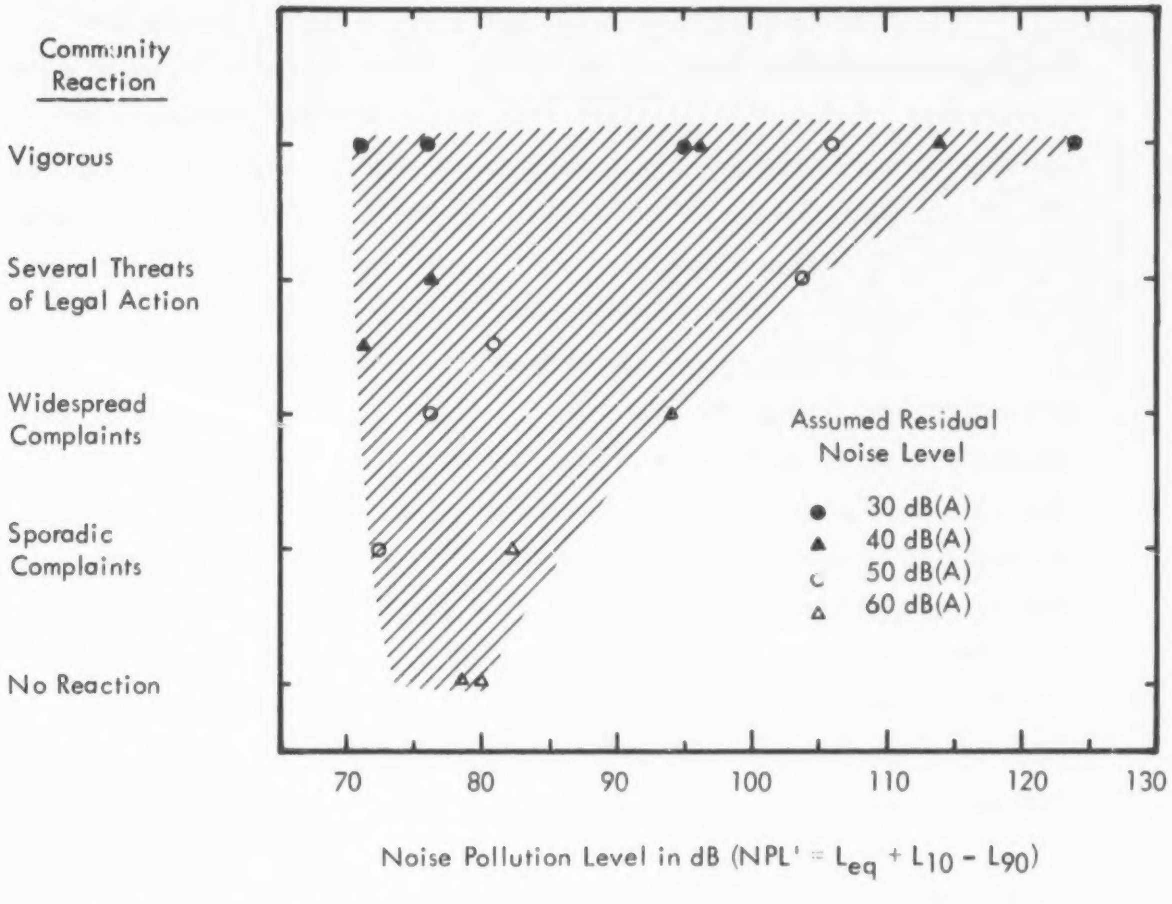


Figure 33. Example of the Relationship Between Noise Pollution Level and Community Reaction for Aircraft Noise, as a Function of Outdoor Residual Noise Level. For the Outdoor Noise Level Without Aircraft L_{eq} and L_{10} were Assumed to be 7 and 10 dB, Respectively, above the Residual Noise Level. Calculations were made for 1, 3, 10 and 30 Aircraft per Hour, Each Having a Maximum Noise Level of 90 dB(A) and an Effective Duration of 5 Seconds. Estimated Community Reaction is Based on Figure 24

A second example was calculated to see the effect of the steady-state intruding noise which was turned on continuously, or for a fraction of the period under consideration. Such source characteristics are common in industrial noise and air conditioning hear exchangers. The example assumed that the residual noise level was 40 dB(A) and the intruding noise was 60 dB(A). Both NPL_e and NPL' were calculated, together with L_{eq} of the intruding noise and L_{eq} of the intruding noise plus the noise which was assumed to exist without the presence of the intruding noise.

The results are presented in Figure 34. When intruding noise is continuous ("on time" fraction of 1.0), $NPL_e = NPL' = L_{eq} = 60$ dB. However, when the source is only on for 50 percent of the time, NPL_e has a maximum of 82.6 dB, 22.6 dB greater than when the source is on all the time. In fact, the NPL_e exceeds 60 dB for all on-time fractions between approximately 0.04 and 1.0. In this example, NPL' is a poor estimator of NPL_e, particularly when the "on time" fraction exceeds 0.1. The reason is that for this steady-state noise, $L_{10} = L_{90}$ for all values of the "on time" fraction which exceed 0.1. Consequently, for intermittent steady-state noise, unlike the fluctuating noises of Figures 32 and 33, NPL' is not an appropriate estimator of NPL_e.

The results of the discussions in this section indicate that NPL is less suitable than ($L_{eq} - L_{90}$) for use in measuring the magnitude of intruding noises relative to residual noises, with respect to their effects on people. This conclusion is particularly relevent to intermittent single-event high-level noises with short duration, as well as intermittent steady-state noises which have "on time" fractions between 0.1 and 0.9.

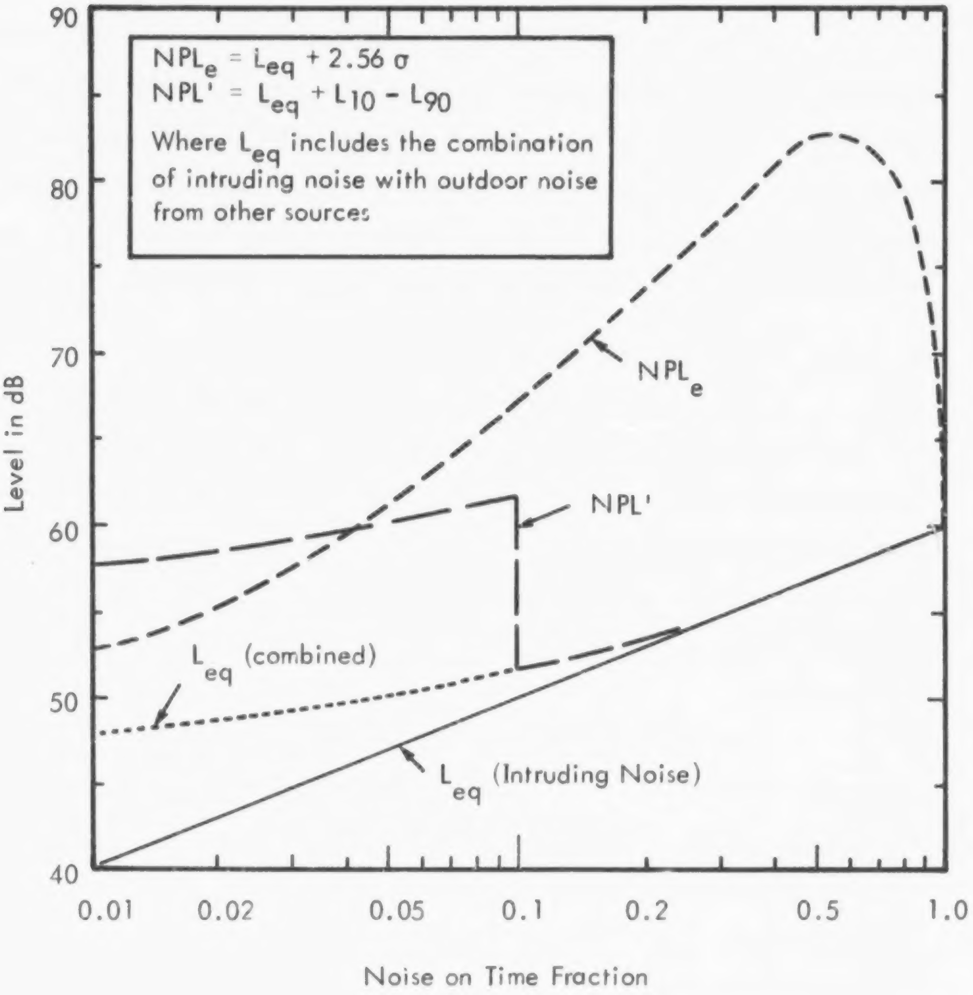


Figure 34. Example of the Effect of Turning on a Steady State Intruding Noise of 60 dB(A) on Noise Pollution Level as a Function of the "On Time" Fraction. The Outdoor Noise Without the Intruding Noise is Specified by L_{10} = 50 dB(A), L_{eq} = 47 dB(A) and L_{90} = 40 dB(A)

6.0 THE GROWTH OF NOISE POLLUTION

There has been considerable public discussion about the growth of noise pollution. Some of this discussion has led to dire predictions that the noise in our environment is increasing by as much as 1 dB per year, or 10 dB per decade. Clearly, such a growth rate, if true, would lead to very severe consequences. To place this problem in perspective, it is useful to examine the possible changes in both the intruding noises and the residual noises over the past few decades.

6.1 Change in Intruding Noises

There has been considerable growth in the number of miles of urban freeways and thruways since 1950. This growth is accompanied by an increase in noise in neighborhoods adjacent to the freeways. Similarly, there has been a significant increase in commercial air travel since 1950.[23] This increase, together with an increase of the noise level of the jet aircraft relative to the older propeller aircraft, and the building of homes around existing civil airports has resulted in a significant number of noise problems.

The amount of land estimated to lie within the CNEL 65 dB contours is illustrated in Figure 35 for both freeways and airports. These estimates[23] show that approximately 2000 square miles of land are bounded by CNEL 65. The actual land use within these impact boundaries (airport property and freeway property have been excluded) is not known. However, if it is assumed that the average use is like the average urban land use, approximately 10 million people would be expected to live in these areas.

These estimates of the impacted area are rather conservative since an intruding noise source which causes a normalized CNEL of 65 dB in an urban residential community is expected to result in widespread complaints. Consequently, the impact of noise pollution extends beyond the CNEL 65 dB boundary, even in an urban residential community. In addition, for suburban communities which have lower residual noise levels, a CNEL of 55 or 60 dB is equivalent to a CNEL of 65 dB in a residential area. Hence, the estimates in Figure 35 are even more conservative.

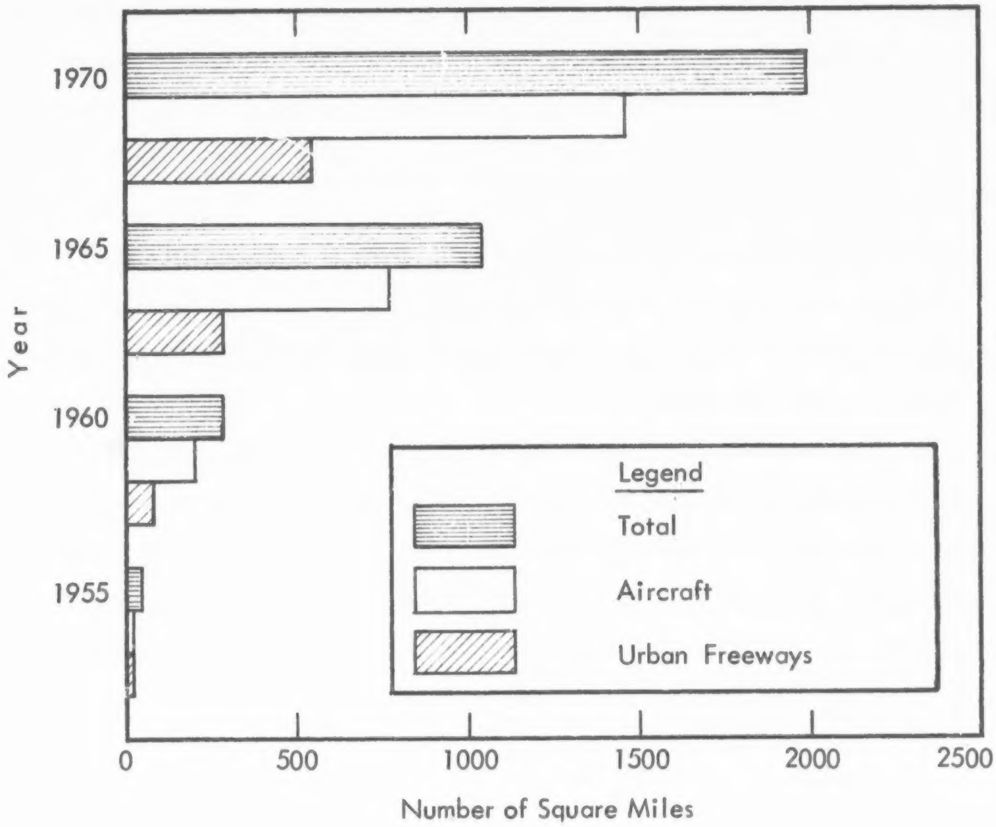


Figure 35. Approximate Growth in Aircraft and Freeway Noise Impacted Land Area Enclosed by Community Noise Equivalent Noise Level of 65 dB. Area for These Two Sources was Very Small Prior to 1955

In addition, the growth of construction activity within the city and industrial plants in the suburbs and rural areas bring increased noise pollution to each affected area. Further, as illustrated in Figure 36, the number of noisy devices such as power lawnmowers and motorcycles has increased from a few hundred thousand units in 1950 to over 20 million in 1970, bringing additional single event noise pollution to the urban and suburban residential areas. Similarly, the introduction and use of recreational vehicles, chain saws, and fully-equipped campers has introduced a new element of noise pollution to the wilderness areas. Even at a remote location on the north rim of the Grand Canyon, the noise from a small propeller-driven private aircraft had a maximum level of 70 dB(A), a 54 dB increase above the daytime residual noise level of approximately 16 dB(A).

The increasing number of sources which produce high noise levels gives clear evidence of the significant growth of noise pollution from intruding sources over the last two decades. Although the majority of this growth occurred in specific areas where freeways or airways were located adjacent to the communities, a significant number of new single event sources were added to all areas from the wilderness to the inhabited suburban and urban residential communities.

6.2 Change in Residual Noise

The question remains whether these additional intrusive noises, together with any changes in the noise characteristics of all other sources, have changed the outdoor residual noise levels in the residential areas which have not had a significant land usage change. It is very difficult to answer this question without the existence of a statistically significant survey of the noise environment in residential areas within the United States, either current or past.

To obtain a "current" estimate, the data for the 11 residential locations in the range survey, Table 3 of Section 3.1, have been combined with data from 17 typical residential locations from another recent survey[19] to give a better composite picture of an "average" urban residential noise environment. The separate and combined data from these two surveys, given in Table 18, indicate that both are from similar

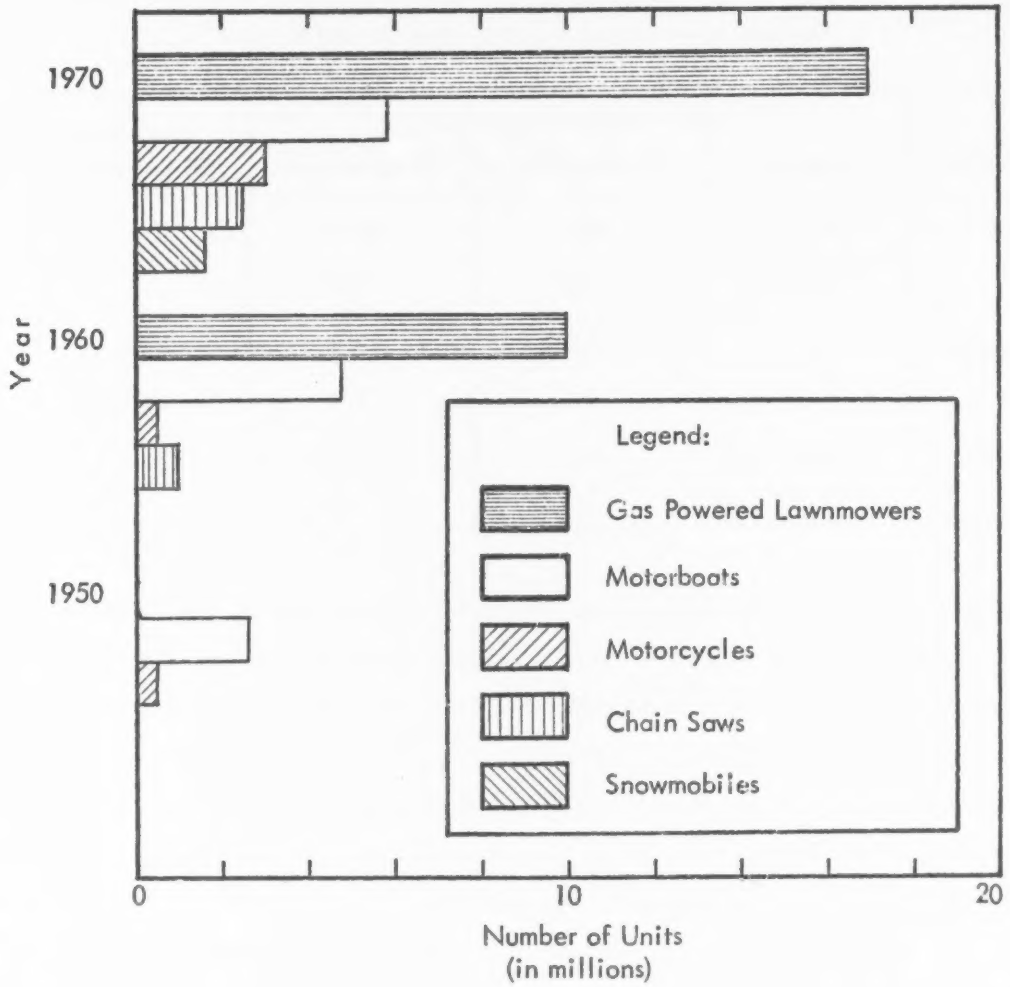


Figure 36. Approximate Growth of a Few Types of Noisy Recreational Vehicles and Outdoor Home Equipment. There were Negligibly Few Gas Powered Lawnmowers, Chain Saws and Snowmobiles in 1950

Table 18

Residual Noise Levels (L_{90}) in dB(A) for 28 Residential Locations Including 11 from this Survey and 17 Locations From Measurements in Los Angeles, Detroit and Boston[19]

Period	Quantity	11 Locations	17 Locations	Combined 28 Locations
Day	L_{90}	45.6	47.5	46.7
	Std. Dev.	4.6	5.8	5.3
Evening	L_{90}	46.7	44.9	45.6
	Std. Dev.	4.1	5.6	5.0
Night	L_{90}	39.8	37.8	38.9
	Std. Dev.	4.1	6.2	5.3

populations, particularly in the daytime. However, since neither survey was undertaken with the intent of statistically sampling a city and there are only 28 locations in total, the results should only be considered indicative of central trends. The "past" data which are available consist of the results of four surveys.[14-16,18] These surveys cover the last 34 years, beginning with the extensive Bell Telephone Company survey of noise in 1937 in residential areas in Chicago, Cleveland and Philadelphia. The comparison of the daytime residual noise data from five surveys is given in Figure 37.

Each survey was different in method, objective and instrumentation, and none compare identical locations. Most were also different in methods of reducing and reporting data as well. Therefore, it was necessary to adjust the data to a common base for comparison. The data for the 1937 and 1968 surveys were published in terms of the median outdoor noise level (L_{50}), and those of the 1957 survey in terms of an energy mean of the noise environment. All three results have been corrected to the residual noise level (L_{90}) by subtracting the average difference of 5 dB found between the median and residual levels in the current data. The mean and 50 percent range for the residual noise levels of the 1947-8 and 1971 surveys are shown as originally presented.

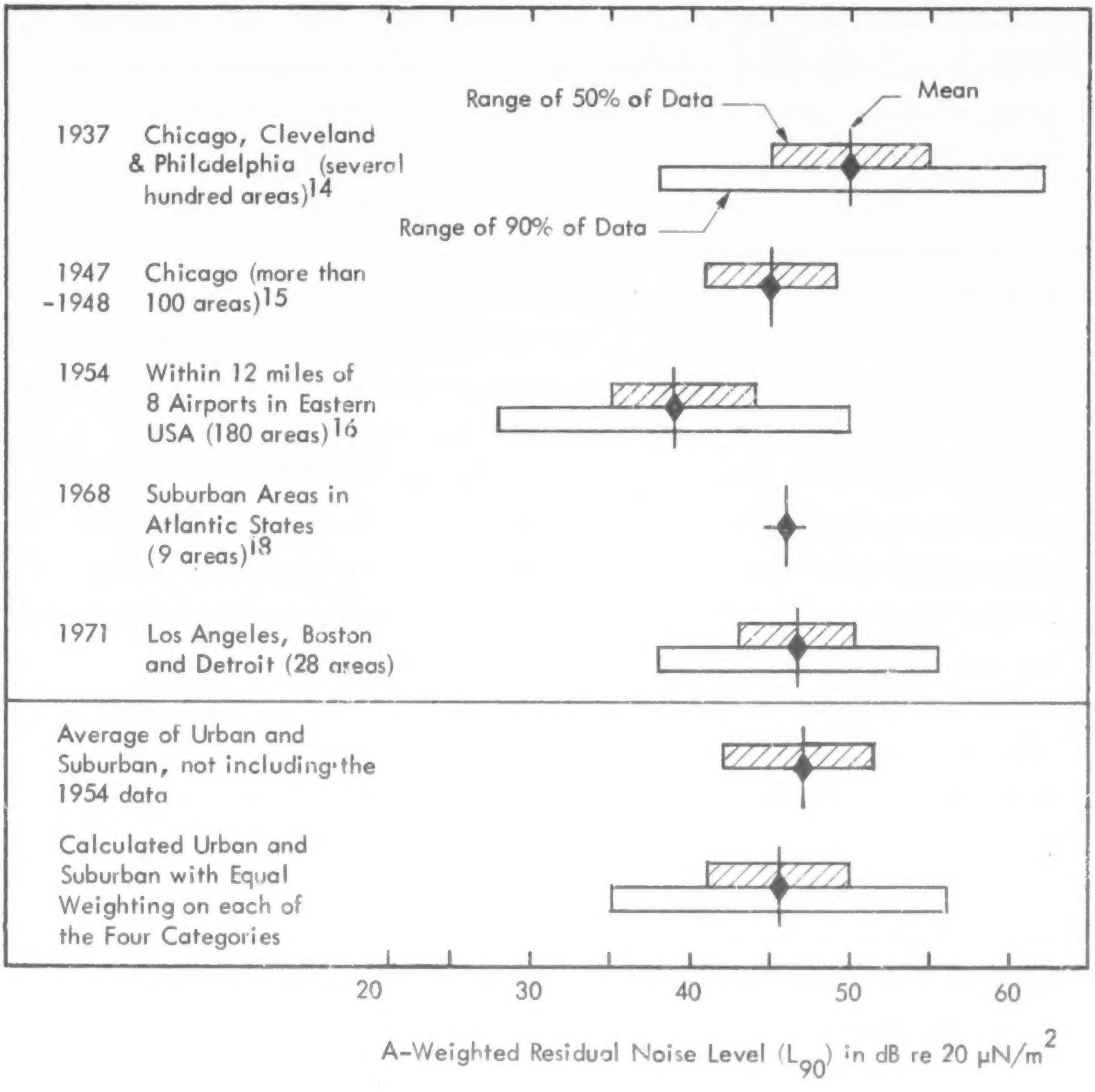


Figure 37. Comparison of Five Surveys of Outdoor Noise Levels in Residential Areas in the United States Between 1937 and 1971. The Data for 1937, 1954 and 1968 Have Been Corrected from Their Published Values to an Approximate Residual Noise Level by Subtracting 5 dB to Account for the Difference Between the Median and Residual Noise Levels

Disregarding the 1954 results, the means of the other four surveys lie between 46 and 50 dB(A) with a grand average of 46.9 dB(A). This value is also close to the average value of 45.5 dB(A) calculated for the suburban categories of quiet and normal suburban, and urban and noisy urban residential areas described in Table 5 of Section 3.1.

The mean value of the 1954 data is 7.7 dB below the 1971 results and 7.9 dB below the average of the other four surveys. This survey was designed to investigate the effect of aircraft noise at many locations under aircraft flight tracks up to 12 miles from each of eight airports, and included rural as well as suburban and urban locations. It is probable that the principal reason for the low values reported by the 1954 survey is that its mix of locations gave significantly more weight to the quiet rural and suburban areas than to the urban and noisy urban residential areas. Similarly, the 1937 survey included city apartment dwellings as well as suburban and urban residential areas with detached dwellings. This difference in emphasis probably resulted in higher emphasis on the "very noisy urban residential" category and explains why these data have the highest reported mean value for the residual noise level.

Thus, it is considered that the 1937 survey was biased to slightly noisier areas, the 1954 survey was significantly biased to the quieter areas, and the three remaining surveys are probably somewhat similar in their distribution of locations among the categories of Table 5. With this perspective, it is concluded that where land use has not changed, there is no strong trend toward an increase in the average suburban and urban residential area residual noise levels over the past 34 years. Further, it appears that the only increase which can be inferred from these data is 2 dB in over two decades based on the difference between the 1947-8 and 1971 results.

This conclusion is also supported by a comparison of the noise at two locations in Los Angeles, where the 1971 data are directly comparable to measurements made in 1955 and 1959. At a normal suburban neighborhood location, where no significant change in land or road use has occurred over 16 years, the two measurements of the residual noise level agreed within 1 dB between 1955 and 1971. In the other case, the 1971 measurements in a residential urban area were approximately 2 dB higher than in 1959, due at least in part to the activation of a new major freeway within 2/3 mile of the location.

Table 19 presents a comparison of residual noise levels in the downtown city. The results for New York, Chicago and London from 1937-1962 show remarkable agreement. However, again direct comparisons at the same location are not available, and the only inference to be drawn is that no significant increases in level are demonstrated for these extremely noisy locations.

Table 19

Comparison of Outdoor Daytime Residual Noise Levels (L_{90})
in the Downtown City

City	Number of Locations	Year	Daytime Residual Noise Level dB(A)	
			Range	Average
New York* Business District[14]	Large	1937	62 to 75	68
Chicago – Heavy Traffic[15]	Large	1947-48	63 to 73	68
London[20]	Approximately 20	1961-62	–	68
Ottawa[21]	One	1968	–	68
Los Angeles (Current survey)	One	1971		73

*Original data which approximated median noise level (L_{50}) corrected to Residual Noise Level by subtracting 5 dB.

The basic conclusion from all of these comparisons is that the average outdoor residual noise level has probably changed only a small amount over the past few decades, in an area which has had a constant land usage throughout the period. However, if the land use has changed at any location, such as from rural to suburban, from suburban to urban, or urban to downtown city, the outdoor residual noise level probably increased significantly (10 dB or more), approximately in accordance with the values in Table 5. Consequently, even if the residual noise level for a given category of neighborhood has not changed, the sprawl of the cities and the suburban expansion during the post war period has significantly increased the number of people impacted by urban noise. In addition, at many locations, the outdoor energy equivalent and maximum noise levels has increased significantly because of the addition of new intruding noise sources, such as an electric power plant, a freeway, or a jet aircraft overflight path.

Thus, in summary, the growth of noise pollution is principally associated with the spread of areas characterized by high noise levels, the growth in numbers of noisy devices used for recreation and labor saving, and the construction of freeways and increase in use of airways by noisy aircraft near residential communities.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The data and discussions in this section lead to several significant conclusions and recommendations regarding the nature of noise pollution and the methods of measuring its magnitude. Although many of these conclusions must be regarded as tentative, because of the lack of a statistically sound community noise baseline, the general trends appear straightforward and give useful perspective for the overall nature of the problem.

7.1 Conclusions

The principal conclusions are:

Range of Outdoor Environments

- The outdoor daytime residual noise level in a wilderness, such as the Grand Canyon rim, is of the order of 16 dB(A), on the farm it is of the order of 30 to 35 dB(A), and in the city it is of the order of 60 to 75 dB(A). These increases in noise level, from wilderness to farm and to city, are the result of man's activities and his use of machines.
- Significant errors may be expected in the measurement of outdoor noise levels in environments characterized by single event noise intrusions, unless the duration of the measurement samples is sufficiently long.
- The mean (arithmetic average) and median (L_{50}) data obtained at the 18 locations in this survey were generally within one dB of each other, with a standard deviation of 0.8 dB. Therefore, the arithmetic average of many sequential measurements, as read on a sound level meter, should be a good estimate of the statistical median (L_{50}).

- The residual noise level read on a graphic level recorder for the data in this survey was found to be about 1 dB less than L_{90} and one dB greater than L_{99}, both with a standard deviation of approximately 2 dB.
- The maximum noise level measured in an hour was found to be significantly higher than both L_{10} and L_1 at almost all locations.

Intruding Noises

- Areas in which the daytime outdoor median noise level exceeds the range of 56 to 60 dB(A), categorized as "very noisy urban", are not well suited to detached residential housing, since normal voice conversation outdoors is limited to distances of less than 6 to 10 feet between talker and listener. Also, when the noise level is above this range, it is not possible to have relaxed conversation in a living room at a distance of 10 feet with windows or sliding glass doors fully opened.
- Areas in which the daytime outdoor median level exceeds 66 dB(A) are not suited to apartment living unless the buildings are air-conditioned so that the windows may be kept closed to enable relaxed conversation indoors. If the outdoor median noise levels are above 71 dB(A), special soundproofing is necessary to preserve the indoor noise environment, even with windows closed.
- The outdoor residual noise level in a suburban and urban residential communities serves the useful function of providing speech privacy between neighbors. Therefore, the requirements for speech privacy should be considered in determining the lower limit of a desirable residual noise level in each type of community.

- Maximum noise levels below 72 dB(A) for individual single events have been judged acceptable in one series of subjective tests, which is consistent with the apparent general acceptability of maximum levels of 62 - 70 dB(A) resulting from normal operation of a standard passenger automobile on a residential street.

Community Reaction to Noise Intrusion

- The correlation of community reaction with the Community Noise Equivalent Level (CNEL) normalized by the method of Rosenblith and Stevens, appears to give reasonable predictions of community complaints to noise intrusion, with 90 percent of the data within ± 5 dB of the mean relationship between the normalized magnitude of the intruding noise and the degree of community reaction.

- The data indicate that no reaction should be expected to occur when the normalized CNEL of the intruding noise is less than 2 dB above the daytime median noise level, or equivalently, approximately 7 dB above the residual noise level. However, some social surveys indicate that when the intruding noise equals this level, approximately 20 percent of the population is "very much annoyed," although 45 percent are only "a little," or "not at all annoyed."

- The significant complaint reactions from the 55 community reaction cases and the approximate percentage of the population "very much annoyed" and "only a little" or "not at all annoyed" from the London study are given in Table 20.

Table 20

Summary of Expected Community Reaction and Approximate Annoyance as a Function of Normalized Community Noise Equivalent Levei

Expected Community Reaction	Approximate Difference Between Normalized CNEL and Average Daytime Residual Noise Level (L_{90}) in dB		Approximate Percent Very Much Annoyed	Approximate Percent Little or Not Annoyed
	Mean	Range of Data		
No reaction	7	2 to 13	20	45
Sporadic complaints	11	8 to 13	26	37
Widespread complaints	17	12 to 24	37	26
Threats of legal action	26	23 to 29	60	14
Vigorous action	33	28 to 39	≈ 87	≈ 7

- To measure the magnitude of intruding noises, relative to community reaction. Noise Pollution Level was found to be less suitable than a quantity equal to the difference between the energy equivalent noise level (L_{eq}) and L_{90}.

Growth of Noise Pollution

- The limited available data from community noise surveys conducted over the past 34 years indicate that little increase has occurred in the residual noise level, except where land usage has changed. Where such change has occurred, the noise has generally increased, probably in accordance with the expected change between land use categories in Table 5, such as plus 10 dB from rural to suburban, or plus 20 dB from rural to noisy urban. A significant spread of noise pollution has occurred in this manner because of the large growth of the urban and suburban areas, and their populations, in the last 20 to 30 years.

- A significant increase of noise pollution in the past 20 years has resulted from the rapid growth of commercial aviation and from its use of jet aircraft which are about 10 to 20 dB noisier than the piston engined aircraft that were replaced. A somewhat lesser, but still significant, increase of noise pollution has resulted from the construction and use of freeways which are located within urban and suburban residential areas. It is estimated that at least 2000 square miles of urban and suburban areas have been severely impacted by noise from these two major sources, with lesser degree of impact extending over a much larger area.
- The rapid increase in popularity and use of noisy recreational vehicles and home lawn care equipment powered by poorly muffled internal combustion engines has contributed to noise pollution in both the wilderness and the residential neighborhood.

7.2 Recommendations

Noise pollution in the community is an extremely complex problem, caused by a variety of sources, and measured in terms of its differing effects on people. To approach this problem requires a systematic approach to the measurement and prediction of community noise, establishment of noise quality goals, control of the basic noise characteristics of the various important sources, community planning for and regulation of noise, and continued research to better understand the effects of noise on people and to improve noise control technology.

The following recommendations address part of this overall problem:

Measurement, Prediction and Goals

- Accomplish a nationwide community noise survey with sufficient locations to have statistical significance to obtain:
    1. National community noise baseline.
    2. Opinions of the noise environment for each location.
    3. Definition of speech privacy requirements.
    4. Definition of minimum requirements and procedures for noise monitoring systems.
    5. Data input to noise quality goals.
    6. Data for improving prediction model for community noise.
- Plan and conduct one or more metropolitan areawide monitoring demonstration programs to obtain total effect of aircraft and freeway noise in residential areas and to further refine monitoring methods and techniques.
- Review and update existing analytical methods for predicting outdoor noise levels in the community from transportation sources, including obtaining any necessary physical data on attenuation.
- Establish noise quality goals for the indoor and outdoor environment, covering both constant and intermittent single or multiple-event noise.

Control of Basic Source Noise, Community Planning and Regulation

- Establish source noise standards and goals, consistent with the community noise quality goals for all major source categories, including all transportation and recreational vehicles, construction equipment, lawn care equipment, and air conditioning equipment.

- Establish noise labeling procedures for all consumer products which produce noise.
- Develop guidelines for achieving acceptable freeway and highway noise levels, incorporating the effects of source noise reduction, barriers, and other design elements.
- Develop a model noise ordinance for use by cities and towns.
- Develop model building codes which include noise performance criteria.
- Define aircraft noise goals which are compatible with the community and the future air transportation system.

Research

- Work with appropriate federal agencies to support research funding to develop the technology for quieter aircraft and their operation.
- Conduct research to improve understanding of effects of noise on people:
    1. Correlate health records versus noise exposure around major metropolitan airports.
    2. Perform experiments in sleep disturbance to determine importance of community noise in sleep disturbance with attention to characteristics and number of noise events versus steady state background.
    3. Obtain better definition of the role of short-time single-event noise interruption in speech and telephone conversation, and TV and radio listening.
    4. Ascertain the relative importance of indoor and outdoor environment on community and individual reaction to noise.

5. Determine noise criteria for people in outdoor areas such as parks.

- Conduct demonstration programs in residential housing to find relationship between room noise reduction and human reaction to develop better criteria for building wall transmission loss, and to provide design goals for reduction of traffic noise for buildings near major freeways.
- Conduct research towards quieting city street canyons through development and application of outdoor acoustical absorbing material to building exterior surfaces.

REFERENCES

1. "Report to the President and Congress on Noise," U.S. Environmental Protection Agency, December 31, 1971.

2. Young, R.W., "Measurement of Noise Level and Exposure," p. 45, Transportation Noises, University of Washington Press, 1970.

3. "American National Standard Specification for Sound Level Meters," ANSI S1.4-1971, American National Standards Institute, Inc.

4. Fletcher, H. and Munson, W.A.,"Loudness, Its Definition, Measurement and Calculation," I. II. Audio 41, 40, 53, 1957.

5. Stevens, S.S., "The Calculations of the Loudness of Complex Noise," J. Acoust. Soc. Am., 29, 603-606, 1957.

6. Stevens, S.S., "Procedure for Calculating Loudness: Mark VI," J. Acoust. Soc. Am., 33, 1577-1585, 1961.

7. Stevens, S.S., "Assessment of Noise: Calculation Procedure Mark VII," Paper 355-128. Laboratory of Psychophysics, Harvard University, Cambridge, Mass., December 1969.

8. Zwicker, E.,"Ein Verfahren zur Berechnung der Lautstarke. (A Means for Calculating Loudness.)"Acoustica 10, 304, 1960.

9. Kryter, Karl D., "Perceived Noisiness (Annoyance)," p.269, The Effects of Noise on Man, Academic Press, 1970

10. Young, R.W., and Peterson, A., "On Estimating Noisiness of Aircraft Sounds," J. Acoust. Soc. Am., 45, 834-838, 1969.

11. Ollerhead, J.B., "An Evaluation of Methods for Scaling Aircraft Noise Perception," Wyle Laboratories Research Staff Report WR 70-17, Contract NAS1-9257, May 1971.

12. "Procedure for Describing Aircraft Noise Around an Airport," ISO Recommendation R 507, International Organization for Standardization, June 1970.

13. Federal Aviation Regulations, Part 36, "Noise Standards: Aircraft Type Certification," November 1969.

14. Seacord, D.F., "Room Noise at Subscribers' Telephone Locations," J. Acoust. Soc. Am., 12, 183-187, July 1940.

15. Bonvallet, G.L., "Levels and Spectra of Traffic, Industrial and Residential Area Noise," J. Acoust. Soc. Am., 23, 435-439, July 1951.

16. Stevens, K.N., "A Survey of Background and Aircraft Noise in Communities Near Airports," NACA Technical Note 3379, December 1954.

17. Veneklasen, P.S., "City Noise – Los Angeles," Noise Control, July 1956.

18. Donley, Ray, "Community Noise Regulation," Sound and Vibration Magazine, February 1969.

19. Simpson, Myles and Biship, Dwight, "Community Noise Measurements in Los Angeles, Detroit and Boston," Bolt Beranek and Newman Report No. 2078, June 1971.

20. "Noise in Towns," NOISE, Chapter IV, 22-31, Presented to Parliament by the Lord President of the Council and Minister for Science by Committee on the Problem of Noise, July 1963; Her Majesty's Stationery Office, Reprinted 1966.

21. Olson, N., "Statistical Study of Traffic Noise, APS-476," Division of Physics, National Research Council of Canada, Ottawa, 1970.

22. Griffiths, I.D. and Langdon, F.J., J. Sound and Vib. 8, 16, 1968.

23. Wyle Laboratories Research Staff, "Noise from Transportation Systems, Recreation Vehicles and Devices Powered by Small Internal Combustion Engines," WR 71-17, Office of Noise Abatement and Control, Environmental Protection Agency, Washington, D.C., November 1971.

24. Webster, J.C., "SIL – Past, Present and Future," Sound and Vibration Magazine, August 1969.

25. Beranek, L.L., Acoustics, McGraw-Hill Electrical and Electronic Engineering Series, McGraw-Hill Book Co., Inc., 1954.

26. Kryter, K.D., "Speech Communication in Noise," AFCRC-TR-54-52, Air Force Cambridge Research Center, Air Research and Development Command, Bolling Air Force Base, Washington, D.C., May 1955.

27. "American National Standard Methods for the Calculation of the Articulation Index," ANSI S3.5-1969, American National Standards Institute, Inc.

28. Mills, C.H.G. and Robinson, D.W., "The Subjective Rating of Motor Vehicle Noise," Appendix IX, NOISE, Presented to Parliament by the Lord President of the Council and Minister for Science by Committee on the Problem of Noise, July 1963; Her Majesty's Stationery Office, Reprinted 1966.

29. "Selection of a Unit for Specification of Motor Vehicle Noise," Appendix A, Urban Highway Noise: Measurement, Simulation and Mixed Reactions, Bolt Beranek and Newman Report 1505, April 1967.

30. Rosenblith, W.A., Stevens, K.N., and the Staff of Bolt Beranek and Newman, Inc., "Handbook of Acoustic Noise Control, Vol 2, Noise and Man," WADC TR-52-204, Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1953.

31. Stevens, K.N., Rosenblith, W.A., and Bolt, R.H., "A Community's Reaction to Noise: Can It Be Forecast?" Noise Control, 1, 63-71, 1955.

32. Stevens, K.N., and Baruch, J.J., "Community Noise and City Planning," Handbook of Noise Control, Chapter 35, McGraw-Hill Book Co., 1957.

33. Parrack, H.O., "Community Reaction to Noise," Handbook of Noise Control, Chapter 36, McGraw-Hill Book Co., 1957.

34. Stevens, K.N. and Pietrasanta, A.C., and the Staff of Bolt Beranek and Newman, Inc., "Procedures for Estimating Noise Exposure and Resulting Community Reactions from Air Base Operations," WADC TN-57-10, Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957.

35. Galloway, W.J. and Pietrasanta, A.C., "Land Use Planning Relating to Aircraft Noise," Technical Report No. 821, Bolt Beranek and Newman, Inc., Published by the FAA, October 1964. Also published by the Department of Defense as AFM 86-5, TM 5-365, NAVDOCKS P-98, "Land Use Planning with Respect to Aircraft Noise."

36. Galloway, W.J., and Bishop, D.E., "Noise Exposure Forecasts: Evolution, Evaluation, Extensions, and Land Use Interpretations," FAA-NO-70-9, August 1970.

37. Wyle Laboratories Research Staff, "Supporting Information for the Adopted Noise Regulations for California Airports," WCR 70-3(R) Final Report to the California Department of Aeronautics, January 1971.

38. "The Adopted Noise Regulations for California Airports," TITLE 4, Register 70, No. 48 – 11-28-70. Subchapter 6. Noise Standards.

39. "Social Survey in the Vicinity of London (Heathrow) Airport, Appendix XI, NOISE, Presented to Parliament by the Lord President of the Council and Minister for Science by Committee on the Problem of Noise, July 1963; Her Majesty's Stationery Office, Reprinted 1966.

40. "Community Reaction to Airport Noise – Final Report," Volume I, Tracor Document No. T-70-AU-7454-U, September 1970.

41. Borsky, P.N., "Community Reactions to Air Force Noise," WADD Technical Report 60-689, Parts 1 and 2, Wright-Patterson AFB, Ohio, March 1961.

42. Galloway, W.J., and Von Gierke, H.E., "Individual and Community Reaction to Aircraft Noise: Present Status and Standardization Efforts," International Conference on the Reduction of Noise and Disturbance Caused by Civil Aircraft, London, November 1966.

43. Private Communication: To – Mrs. Elizabeth Cuadra, Wyle Laboratories, From – Mr. Erland Jonsson, National Institute of Public Health, Stockholm, Sweden, re: Summary of Swedish Study of Reactions to Aircraft Noise Made in 1959. Communication dated February 20, 1970.

44. Robinson, D.W., "The Concept of Noise Pollution Level," National Physical Laboratory, Aerodynamics Division, NPL Aero Report Ac 38, March 1969.

45. Robinson, D.W., "Towards a Unified System of Noise Assessment," J. Sound and Vibration, 14 (3), p. 279-298, 1971.

46. Bottom, C.G. and Waters, D.M., "A Social Survey Into Annoyance Caused by the Interaction of Aircraft Noise and Traffic Noise," Department of Transport Technology TT-7102, Loughborough University of Technology.

47. Draft ISO Recommendation: "Noise Assessment with Respect to Community Response," No. 1996, November 1969.

APPENDIX A

COMMUNITY NOISE SURVEY

This appendix provides site descriptions, noise data and measurement procedures relating to each of the 18 noise survey locations. Table A-1 provides the letter designations and titles for all locations.

A.1 Descriptive Figures

The descriptive information and data for each location are contained in a series of three consecutive figures. The figures A-1a, A-1b, and A-1c all relate to Location A. Figures A-2a, A-2b, A-2c relate to Location B. Those designations continue through Location R, depicted in Figures A-18a, A-18b, and A-18c. The content of these figures is described in the following paragraphs.

A.1.1 Site Descriptions

Figures A-1a, A-2a, through A-18a describe the type of community represented by the survey site and its geographical location. Each figure contains a local street map, a photograph of the location, a description of the local noise environment, and pertinent comments on microphone location and the measured data. The survey location is indicated on each street map by a black diamond (♦).

A.1.2 24-Hour Time History Records

Figures A-1b, A-2b, through A-18b are 24-hour time history records of A-weighted noise levels for each survey location. These records are portrayed on two facing pages; the first page depicts noise levels for 0000 hours to 1200 hours and the second page depicts noise levels for 1200 hours to 2400 hours.

Data ranging in length from several seconds to several minutes is missing from the 24-hour time history records for some of the survey locations because the recorder was temporarily stopped for system maintenance or adjustment.

During the 24-hour measurements at Locations F and J, the community noise levels occasionally dropped below the noise threshold of the measurement instrumentation. This is indicated by the fairly constant level on the 24-hour recording. This condition also occurred at Location R and is discussed in Figure 18-A. At Locations B, M and O, portions of the 24-hour record which appear to have reached a threshold are actually indicating a constant noise level established by air conditioning systems, blowers, or other continuous local noise sources.

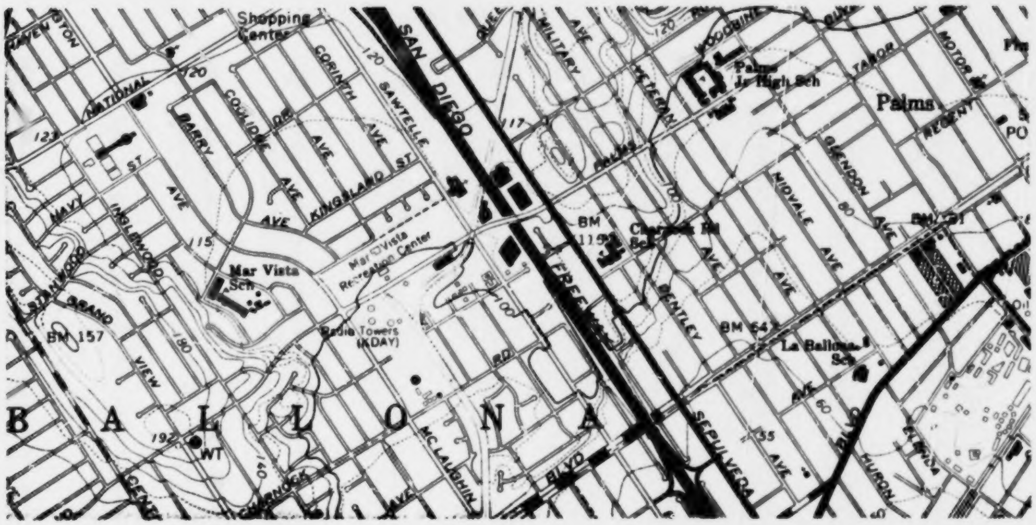
A.1.3 24-Hour Outdoor Noise Summaries

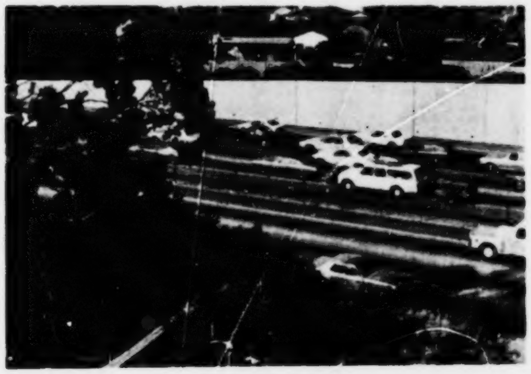
Figures A-1c, A-2c, through A-18c are summaries of the 24-hour outdoor noise levels at each location. These figures provide a statistical portrayal of community noise throughout a 24-hour period. The upper graphs (a) give the maximum and residual noise levels read from a graphic level recorder, together with the hourly and period values of the levels which are exceeded 99, 90, 50, 10, and 1 percent of the time (L_{99}, L_{90}, L_{50}, L_{10}, and L_1), respectively, and the energy mean equivalent level (L_{eq}). The lower graph illustrates the statistical distribution of the noise levels throughout each of the three time periods.

TABLE A-1

Community Noise Survey Locations

Location	Page	Address
A	A-5	Third Floor Apartment, next to Freeway – West Los Angeles, California
B	A-9	Third Floor Downtown Hi-Rise – Los Angeles, California
C	A-13	Second Floor Tenement – Harlem, New York
D	A-17	Urban Shopping Center – Torrance, California
E	A-21	Popular Beach on Pacific Ocean – Corona Del Mar, California
F	A-25	Urban Residential Near Major Airport – Lennox, California
G	A-29	Urban Residential Near Ocean – Redondo Beach, California
H	A-33	Urban Residential, 6 miles to Major Airport – Los Angeles, California
I	A-37	Suburban Residential near R/R tracks – Simi Valley, California
J	A-41	Urban Residential – Inglewood, California
K	A-45	Urban Residential near small Airport – Newport Beach, California
L	A-49	Old Residential near City Center – Los Angeles, California
M	A-53	Suburban Residential at City Outskirts – Pacific Palisades, California
N	A-57	Small Town Residential, Cul-de-Sac – Fillmore, California
O	A-61	Small Town Residential, Main Street – Fillmore, California
P	A-65	Suburban Residential in Hill Canyon – Los Angeles, California
Q	A-69	Farm in Valley – Camarillo, California
R	A-73	Grand Canyon, North Rim – Arizona





Community Description: Large apartment unit, adjacent to San Diego Freeway in a mixed single multiple unit residential neighborhood. Eight-lane major freeway; 0.5 mile to Venice Boulevard; 1.1 miles to Santa Monica Freeway; 1.1 mile to a general aviation airport.

Noise Environment: This location was right next to a major freeway. Freeway traffic produced very high noise levels most of the day and traffic was heavy enough to keep the residual noise levels in the high 70 dB(A) range with a relatively narrow excursion to traffic maximums in the 90 dB(A) range. During the very early morning hours, with light traffic, the noise level went down into the 40 dB(A) range for several brief periods. No other intruding events are readily distinguishable on the 24-hour noise signature. The microphone was positioned 100 feet from the side of the freeway and 45 feet above ground level. It projected 6 feet toward the freeway from a third-floor apartment balcony. The freeway street level was about 30 feet below ground level at the apartment building.

Figure A-1a. Location A – Third Floor Apartment, Next to Freeway – West Los Angeles, California

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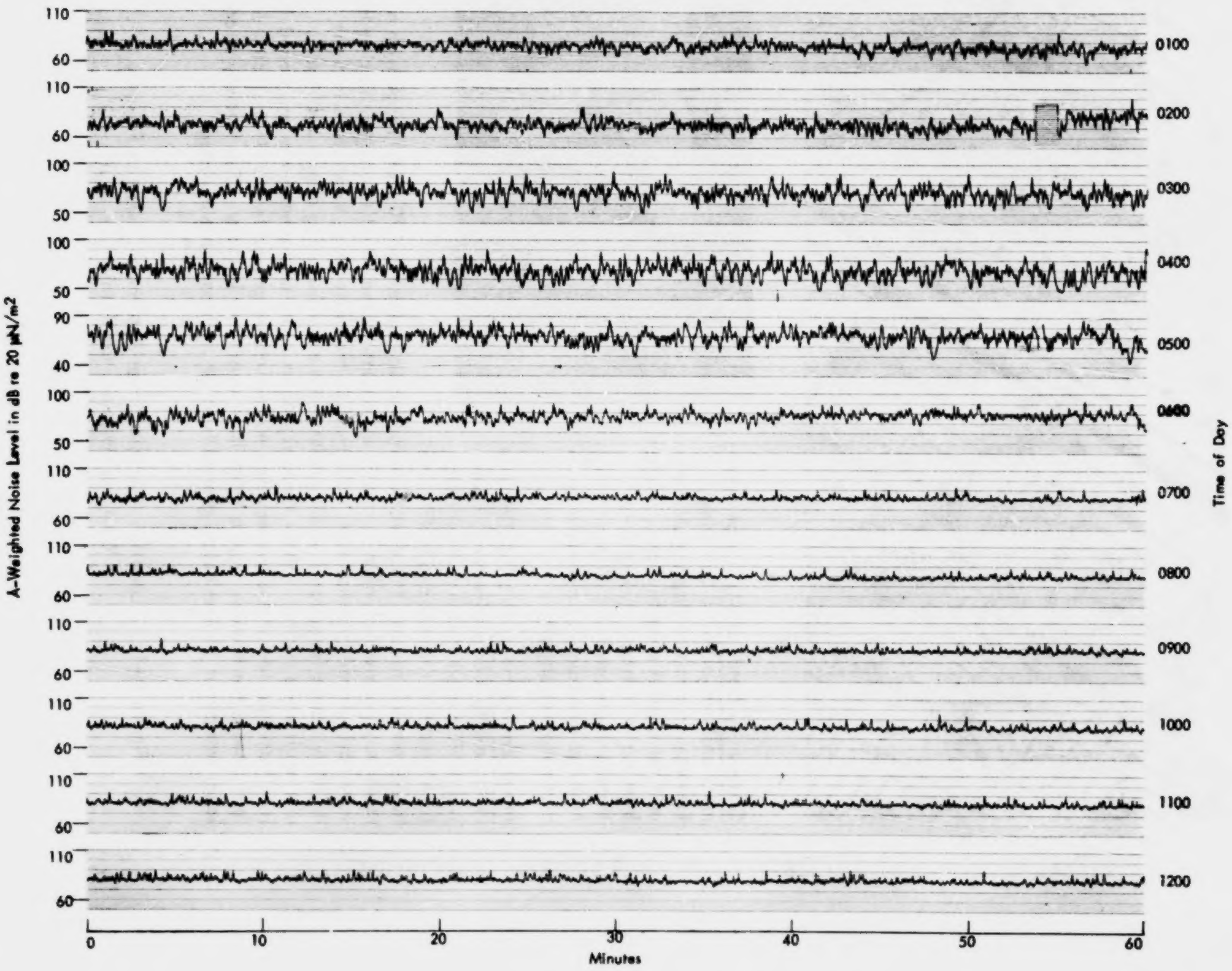
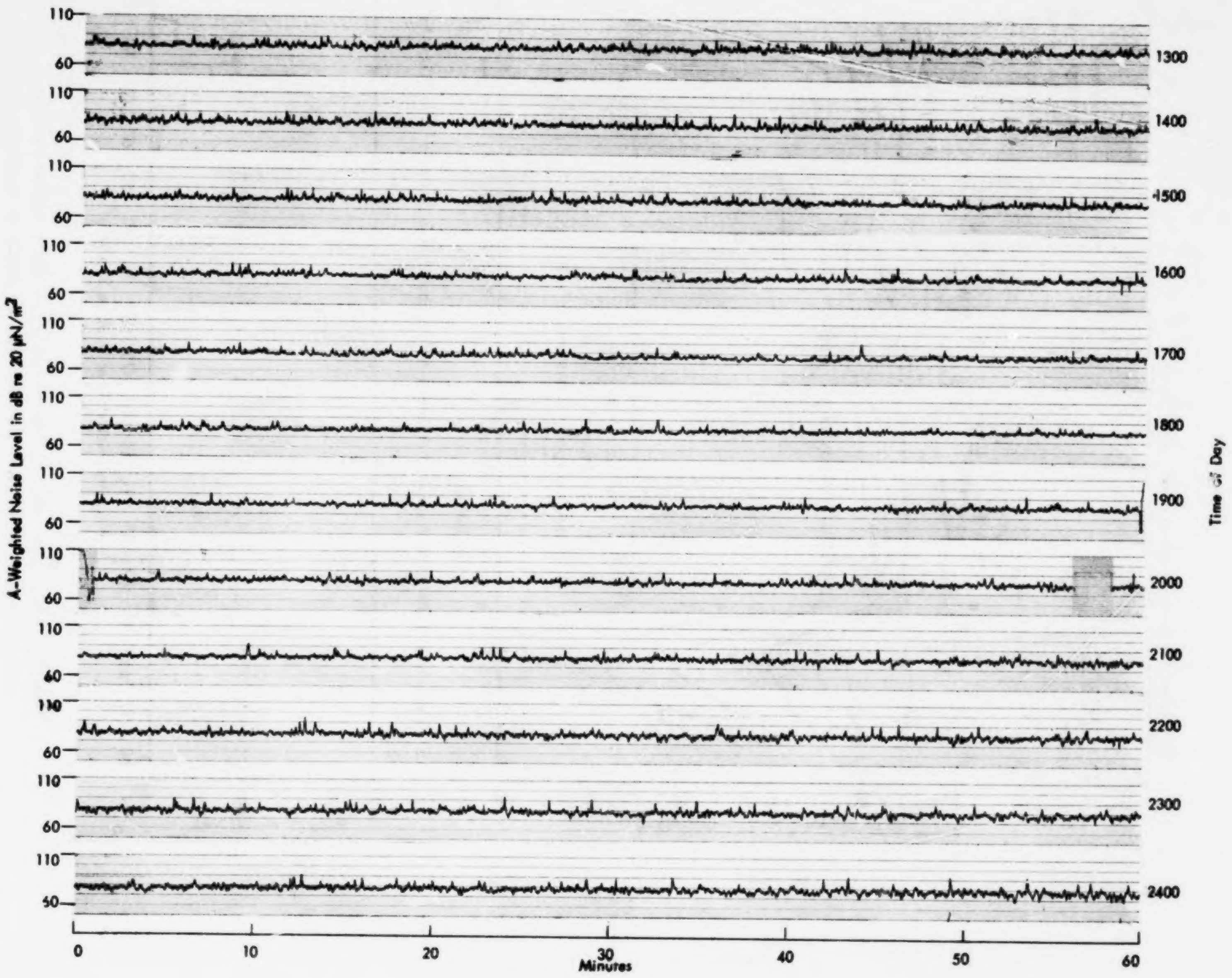
Figure A-1b. Time History

LOCATION A – 0000 Hours to 1200 Hours



LOCATION A – 1200 Hours to 2400 Hours



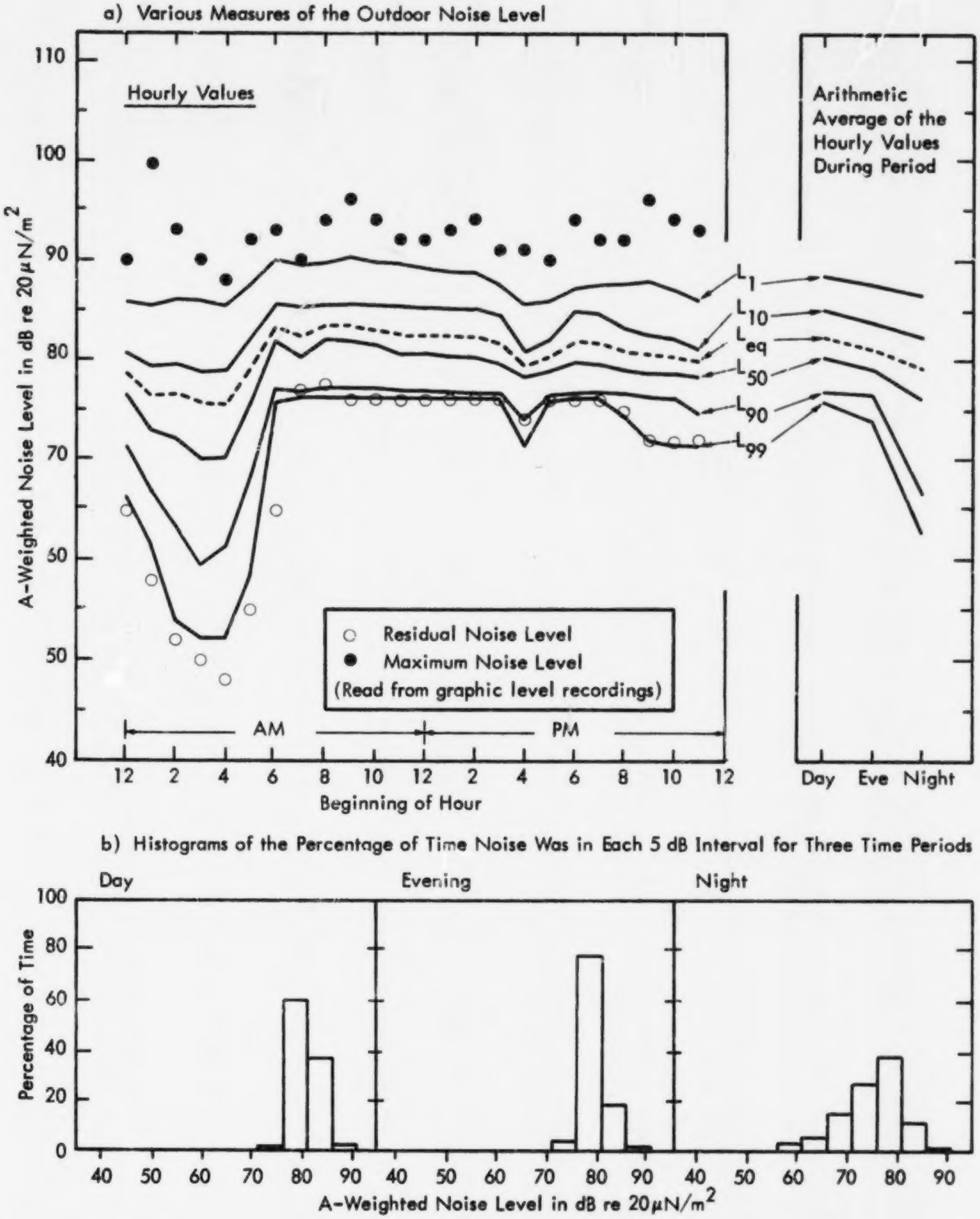
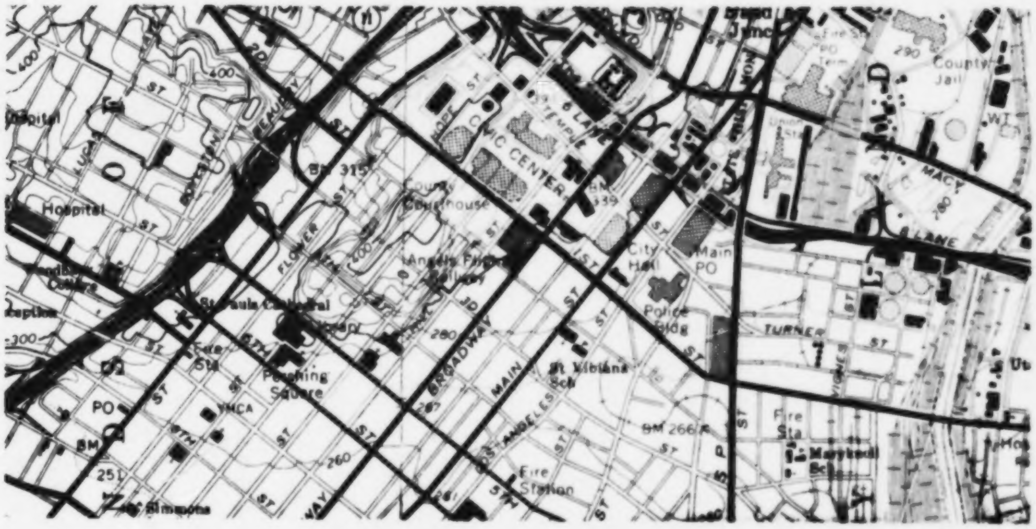
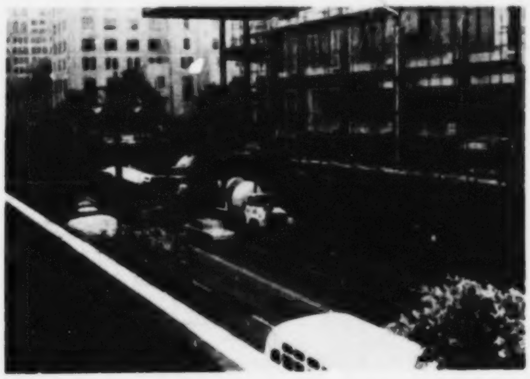


Figure A-1c. Summary of the 24-Hour Outdoor Noise Levels at Location A – Third Floor Apartment, Next to Freeway


Hospital
Hospital
County Jail
CIVIC CENTER
County Courthouse
City Hall
Main PO
Police Bldg
TURNER
MACY
FLOWER
HOPE
BROADWAY
MAIN
LOS ANGELES
St Vibiana's Sch
Pershing Square
YMCA
PO
Fire Sta
Fire Station
BM 315
BM 266
280
260
251



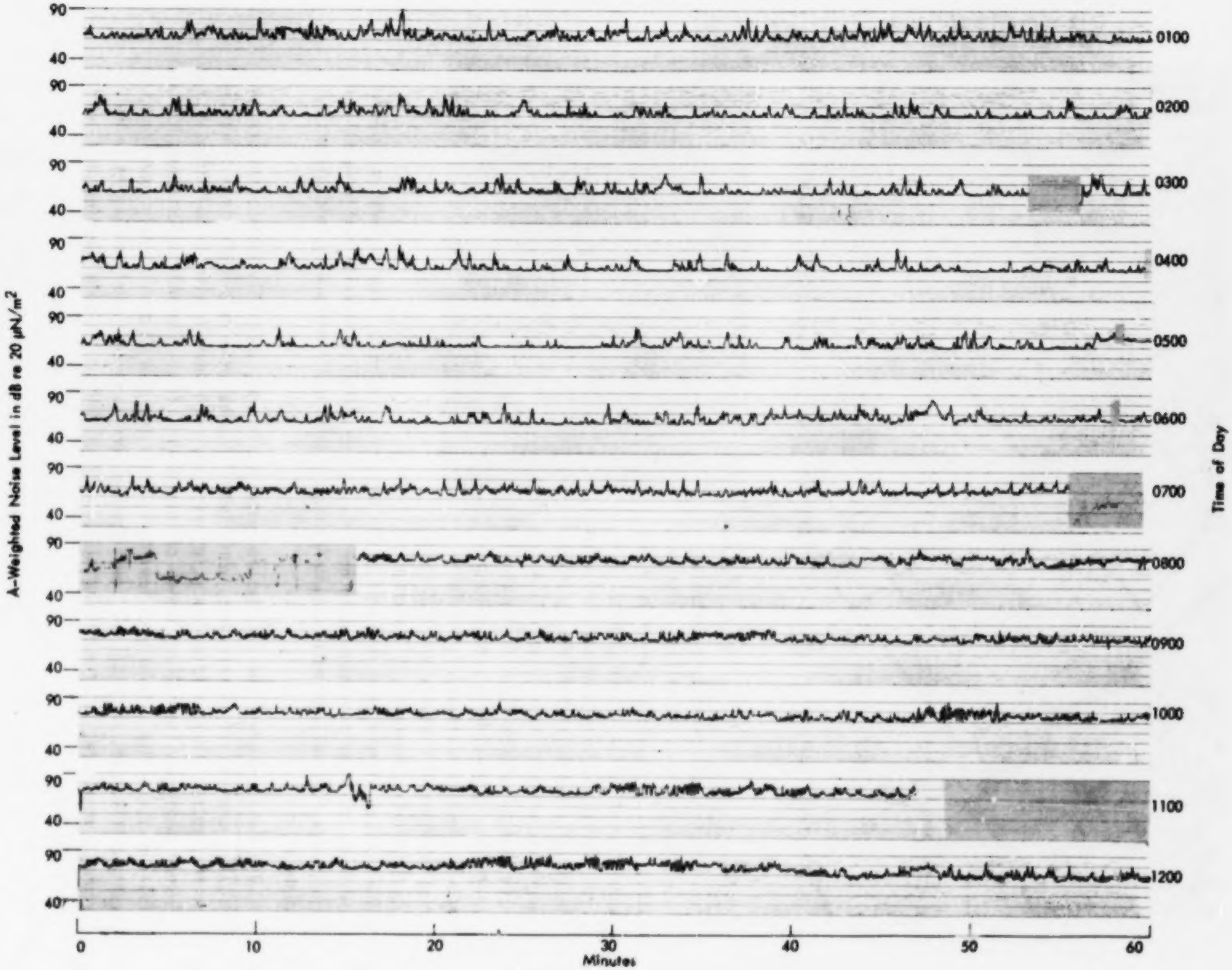
Community Description: Major downtown metropolitan area, undergoing considerable reconstruction. The two major projects were a five-story steel beam construction above ground on a commercial building and subterranean foundation work on a parking garage. The two projects were located side by side directly across the street from the location. Broadway is a four-lane major downtown street, 0.3 mile to the Hollywood Freeway and 0.6 mile to the Harbor Freeway, 1.7 miles to the Golden State-Santa Ana and Santa Monica Freeways. The general area is a network of major downtown arteries serving high rise commercial and governmental buildings, 0.6 mile to railroad station and associated warehousing and industrial district.

Noise Environment: The noticeable intruding noises, primarily from construction trucks, cranes and airwrenches, were superimposed on a very high level of steady traffic noise. Buses and motorcycles were very noticeable within the traffic noise. Sirens produced the highest levels of intruding noises. The microphone was located 30 feet above the sidewalk, 6 feet away from the side of a relatively open parking garage structure. A large air conditioning vent at street level, adjacent to the parking structure, dominated the residual level during the late evening and early morning hours.

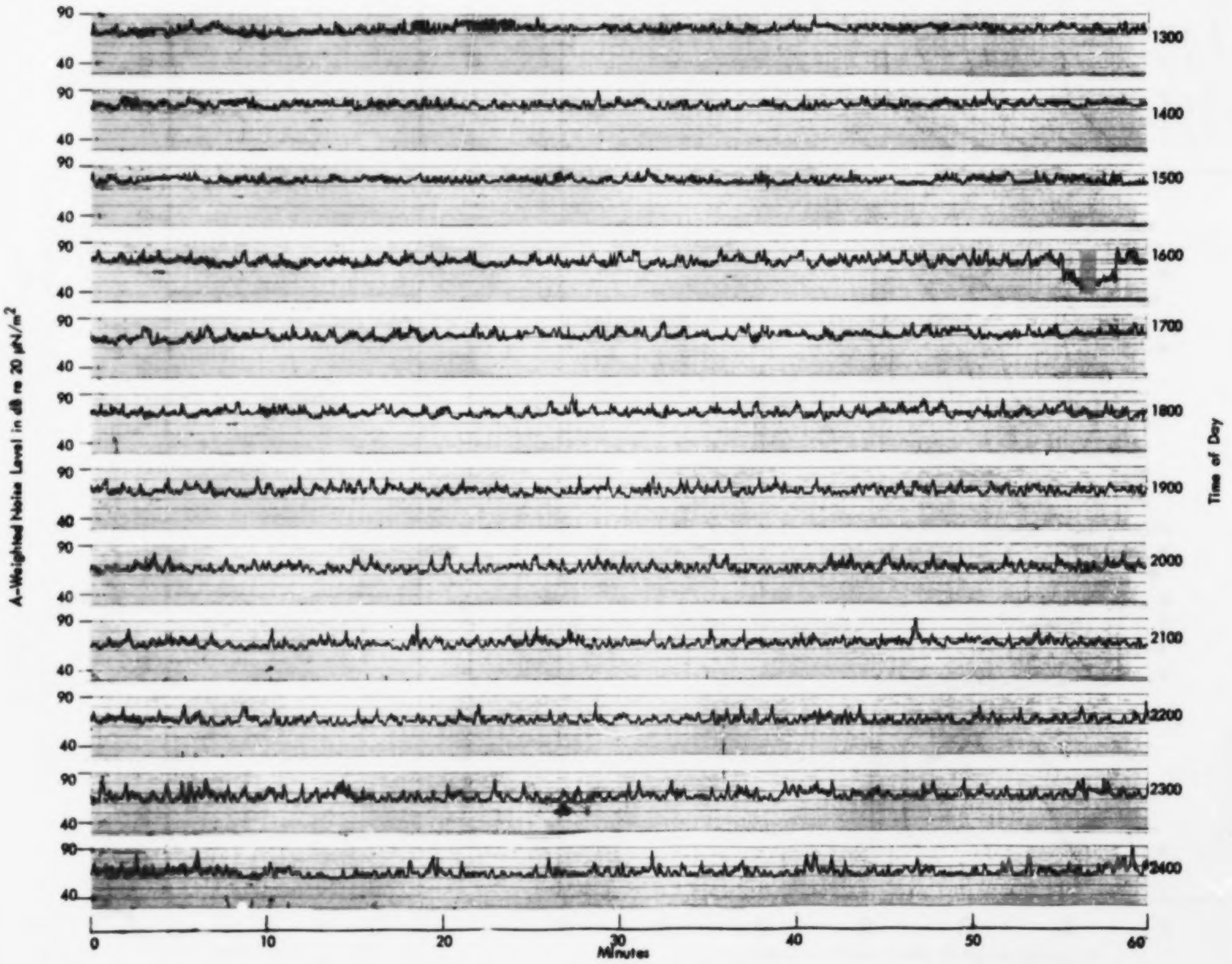
Figure A-2a. Location B — Third Floor Downtown Hi-Rise — Los Angeles, California

Figure A-2b. Time History

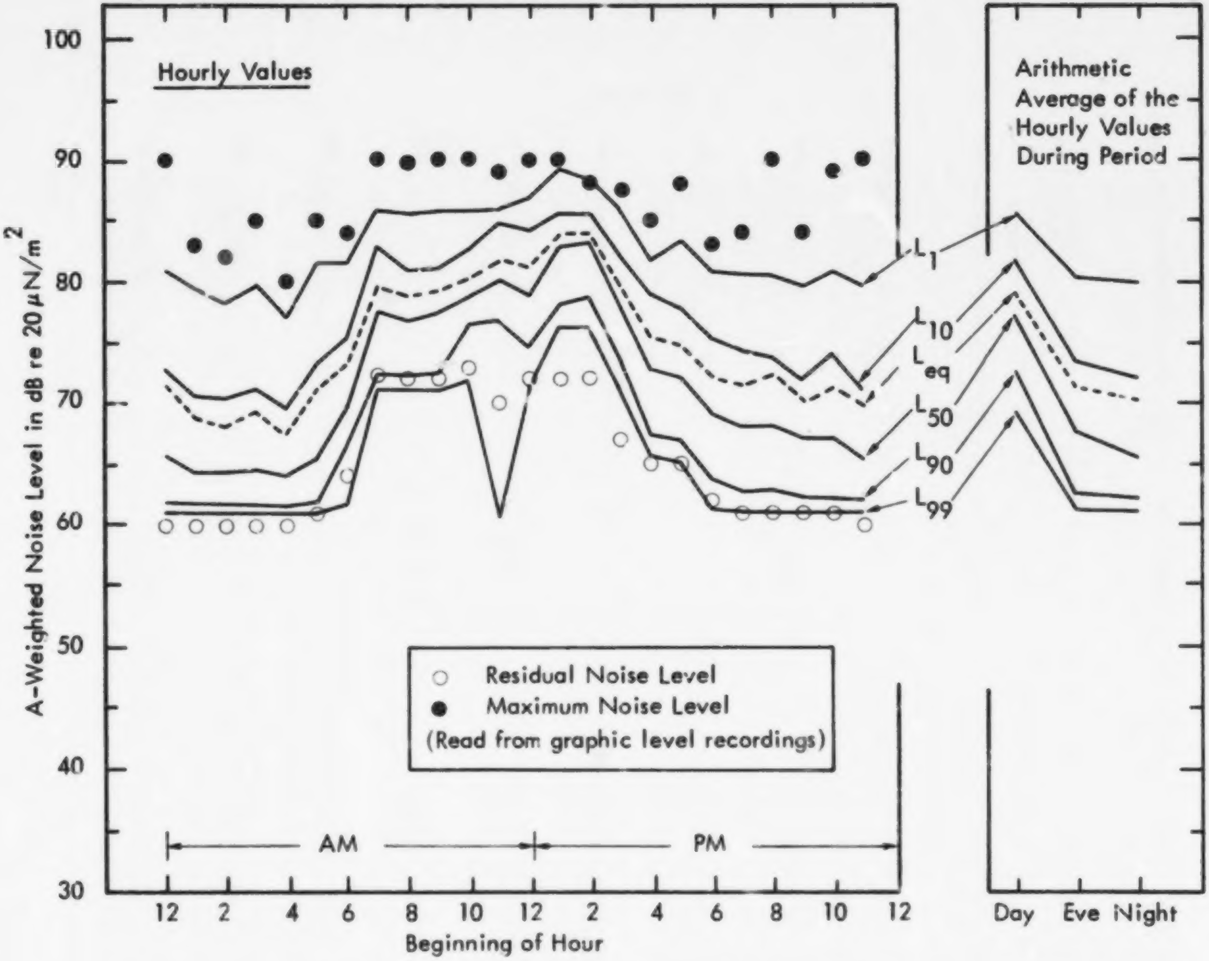
LOCATION 8 – 0000 Hours to 1200 Hours



LOCATION B – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise Was in Each 5 dB Interval for Three Time Periods

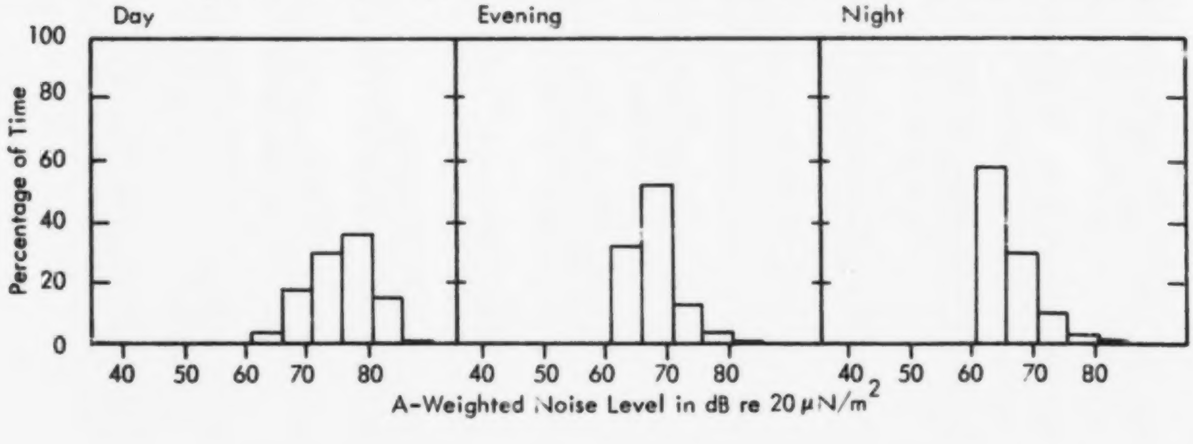
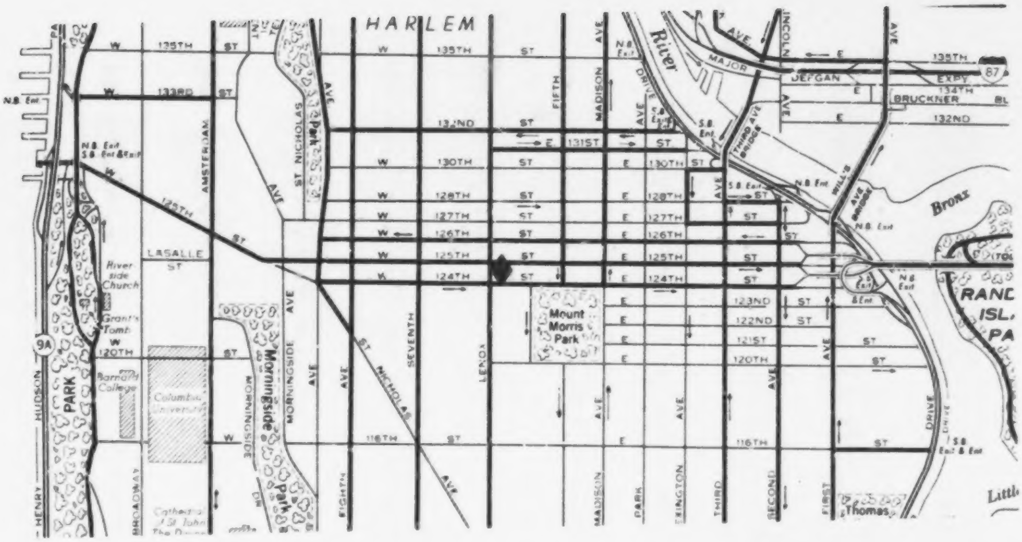


Figure A-2c. Summary of the 24-Hour Outdoor Noise Levels at Location B – Third Floor Downtown Hi-Rise


HARLEM
W 135TH ST
133RD
132ND
131ST
130TH
128TH
127TH
126TH
125TH
124TH
123ND
122ND
121ST
120TH
116TH
125TH ST
LASALLE ST
AMSTERDAM
ST NICHOLAS AVE
MORNINGSIDE AVE
Morningside Park
EIGHTH AVE
SEVENTH AVE
LENOX
FIFTH
MADISON AVE
PARK AVE
LEXINGTON AVE
THIRD AVE
SECOND AVE
FIRST AVE
Mount Morris Park
River
MAJOR DEEGAN
BRUCKNER
Bronx
Riverside Church
Grant's Tomb
Barnard College
Columbia University
HENRY HUDSON PARK
BROADWAY
9A
87
Thomas

WINDSOR CANADIAN

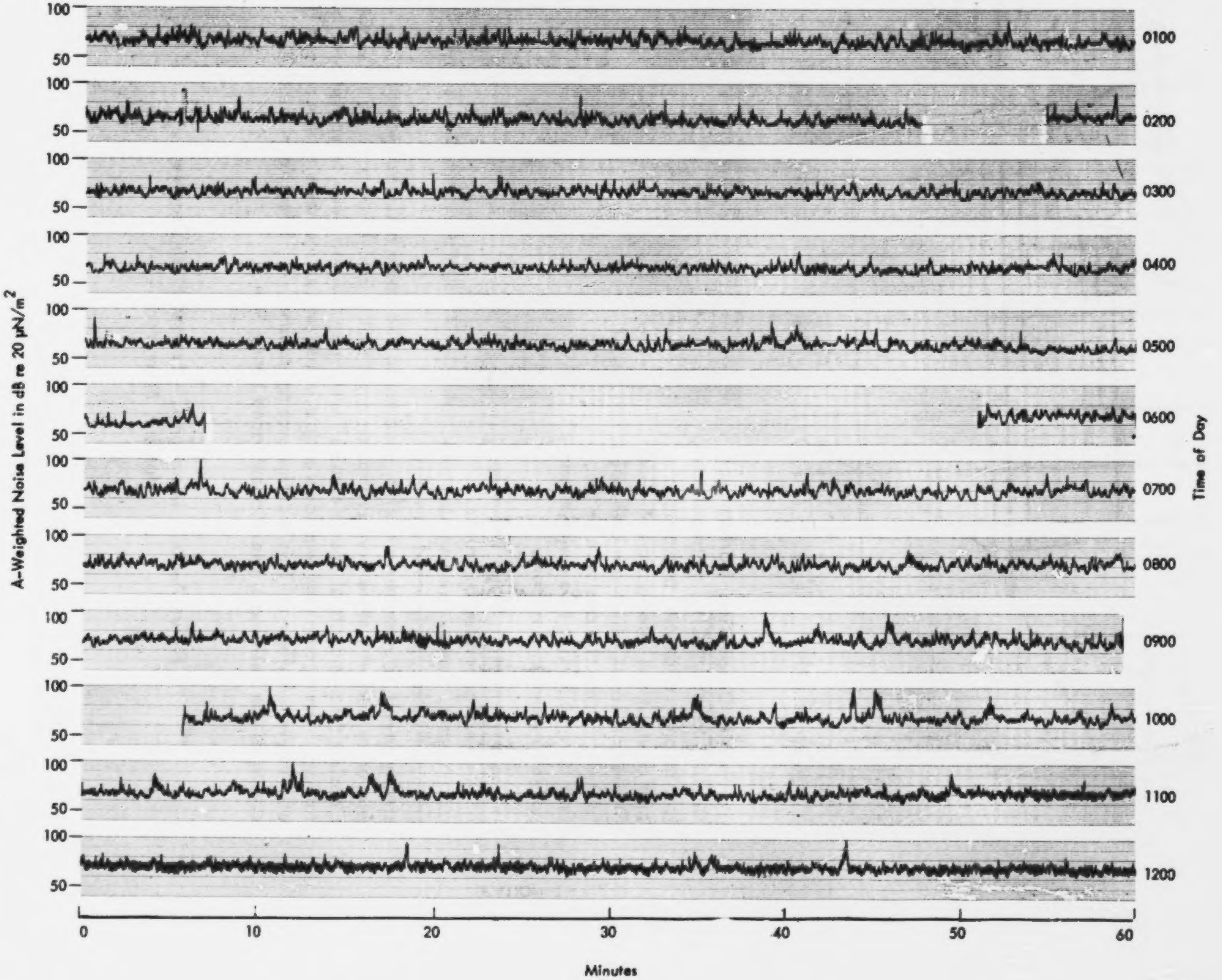
Community Description: Harlem section of New York City; metropolitan low income residential and commercial area; at the intersection of 125th Street and Lenox which are both major four-lane arterials; one mile to the East River; 25 miles to a major metropolitan commercial airport.

Noise Environment: Major intruding noises were generated by trucks, motorcycles, sirens, fire engines, and jet overflights superimposed on fairly steady levels of automobile traffic, loud music and voice announcements being played as part of a store front promotion continually from 10:00 a.m. to midnight. Considerable amounts of "people noise" were noted during times when rain was not falling. The microphone was located just inside an open window on the second floor of a business building. This location was approximately 55 feet from the actual corner of the building. The window faced Lenox Street.

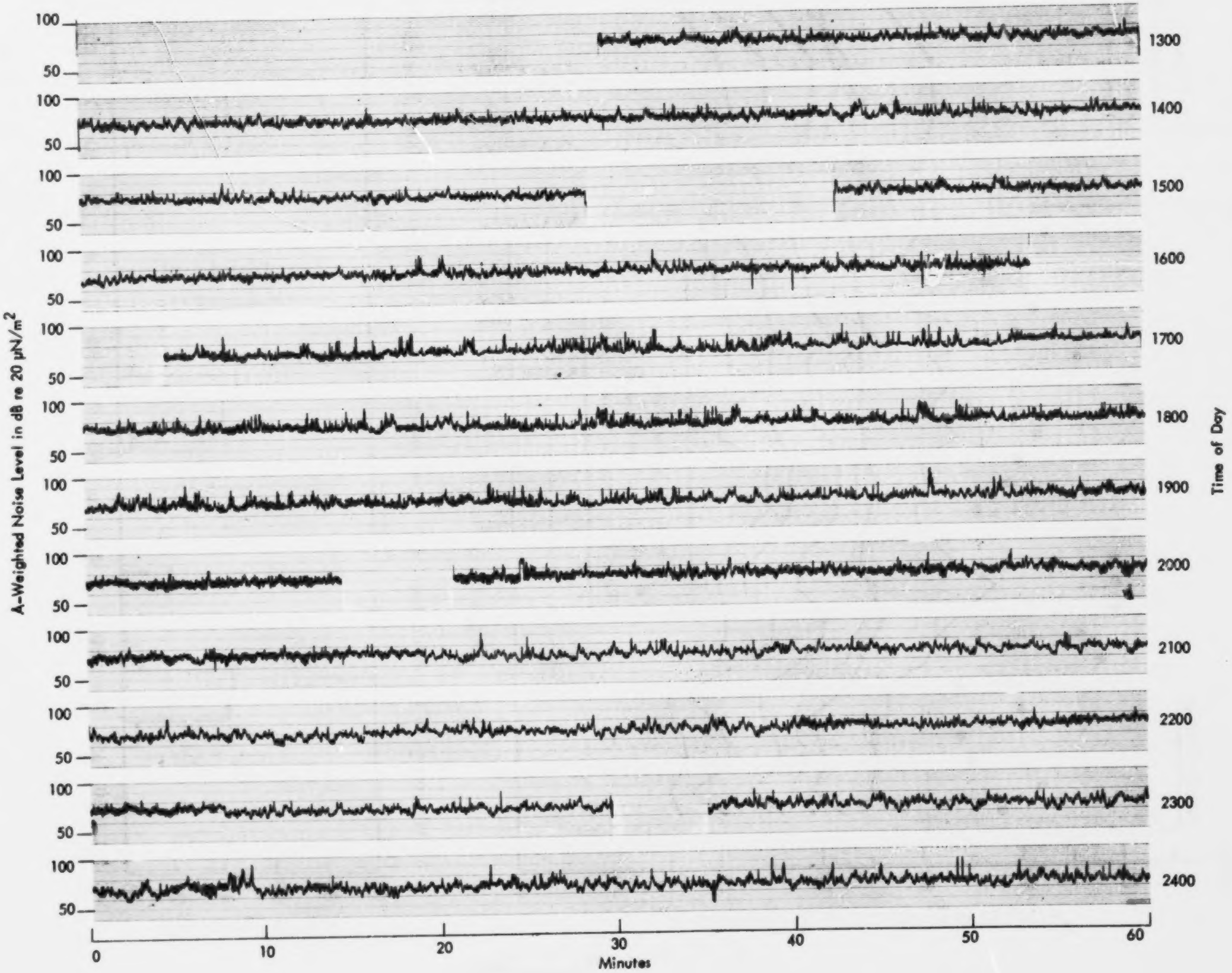
Figure A-3a. Location C – Second Floor Tenement – Harlem, New York

Figure A-3b. Time History

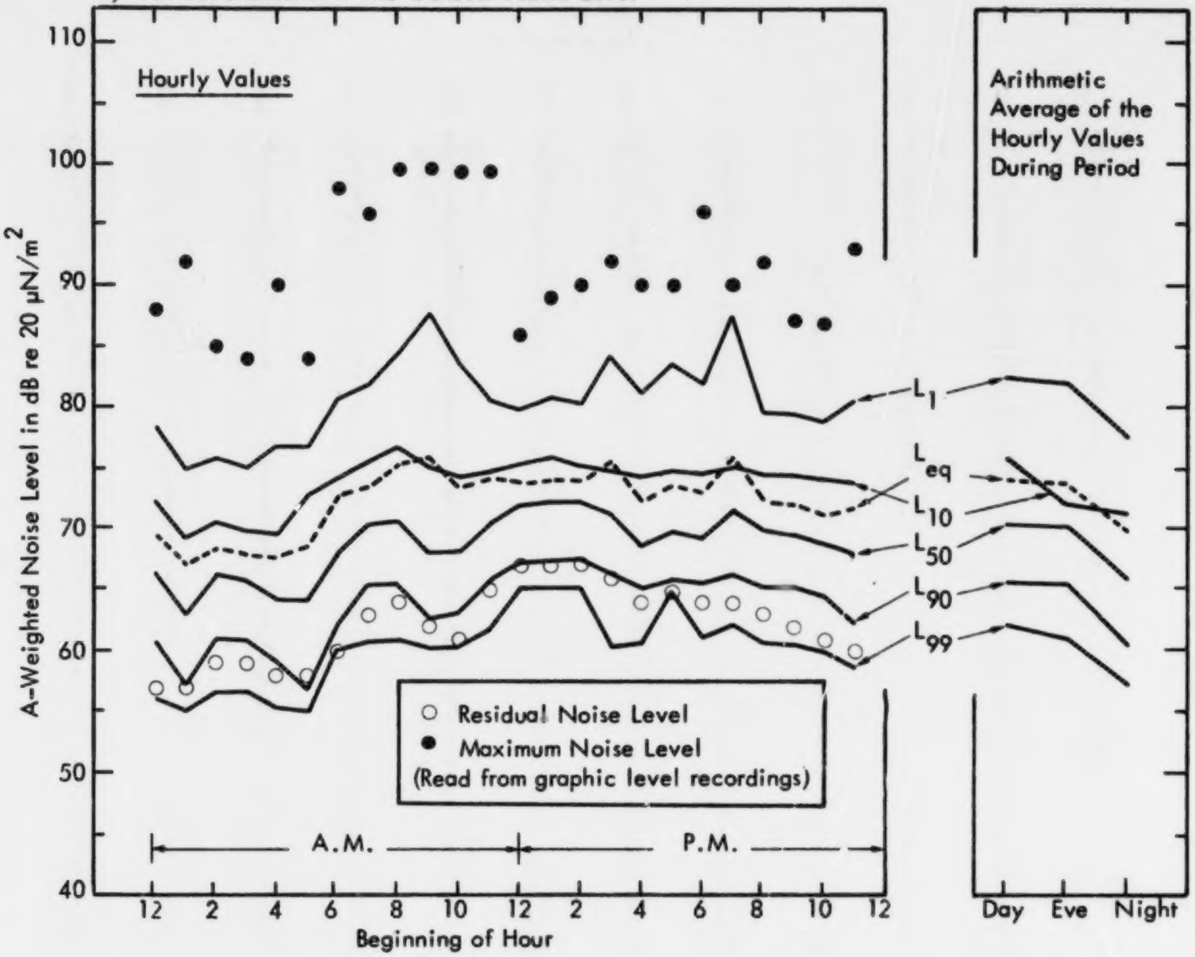
LOCATION C – 0000 Hours to 1200 Hours



LOCATION C -- 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise was in Each 5 dB Interval for Three Time Periods

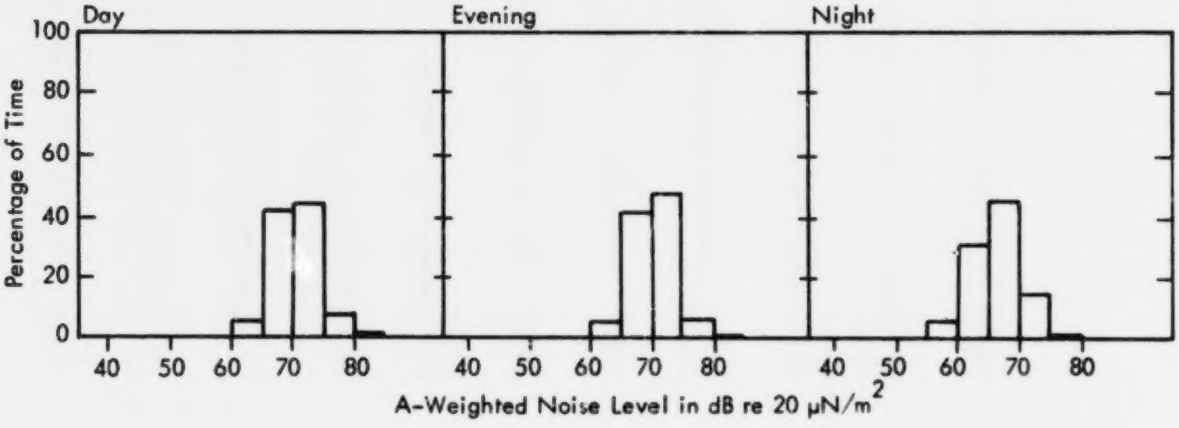
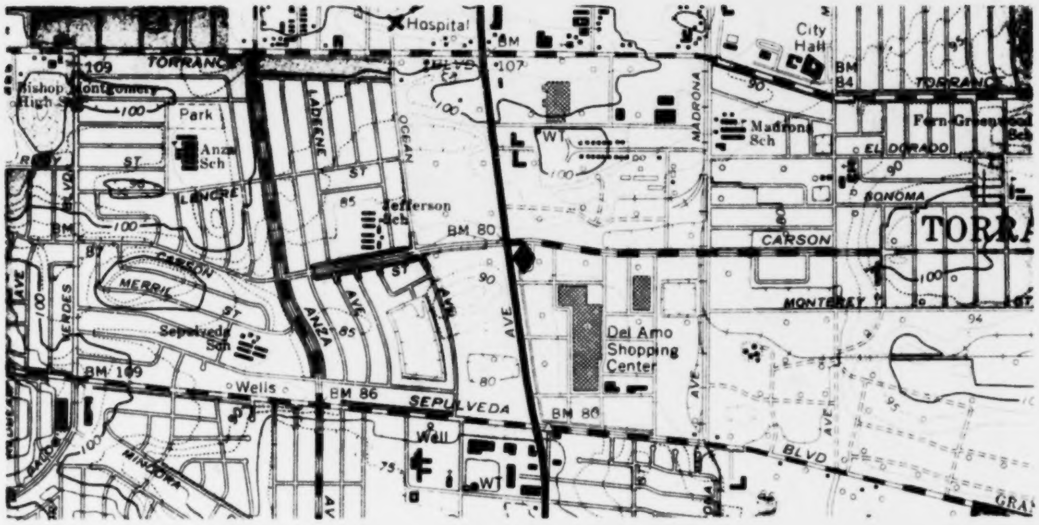
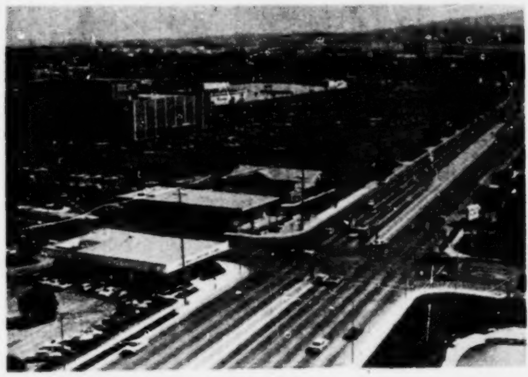


Figure A-3c. Summary of the 24-Hour Outdoor Noise Levels at Location C – Second Floor Tenement


Hospital
City Hall
TORRANCE
BLVD
BM 107
109
Bishop Montgomery High
Park
Anza Sch
LADECNE
OCEAN
MADRONA
Madrona Sch
Fern-Greenwood Sch
EL DORADO
SONOMA
TORRANCE
Jefferson Sch
BM 80
CARSON
MERRILL
ST
Sepulveda Sch
ANZA
AVE
MONTEREY
Del Amo Shopping Center
BM 109
Wells
BM 86
SEPULVEDA
BM 86
BLVD
VERDES
WT
GRA



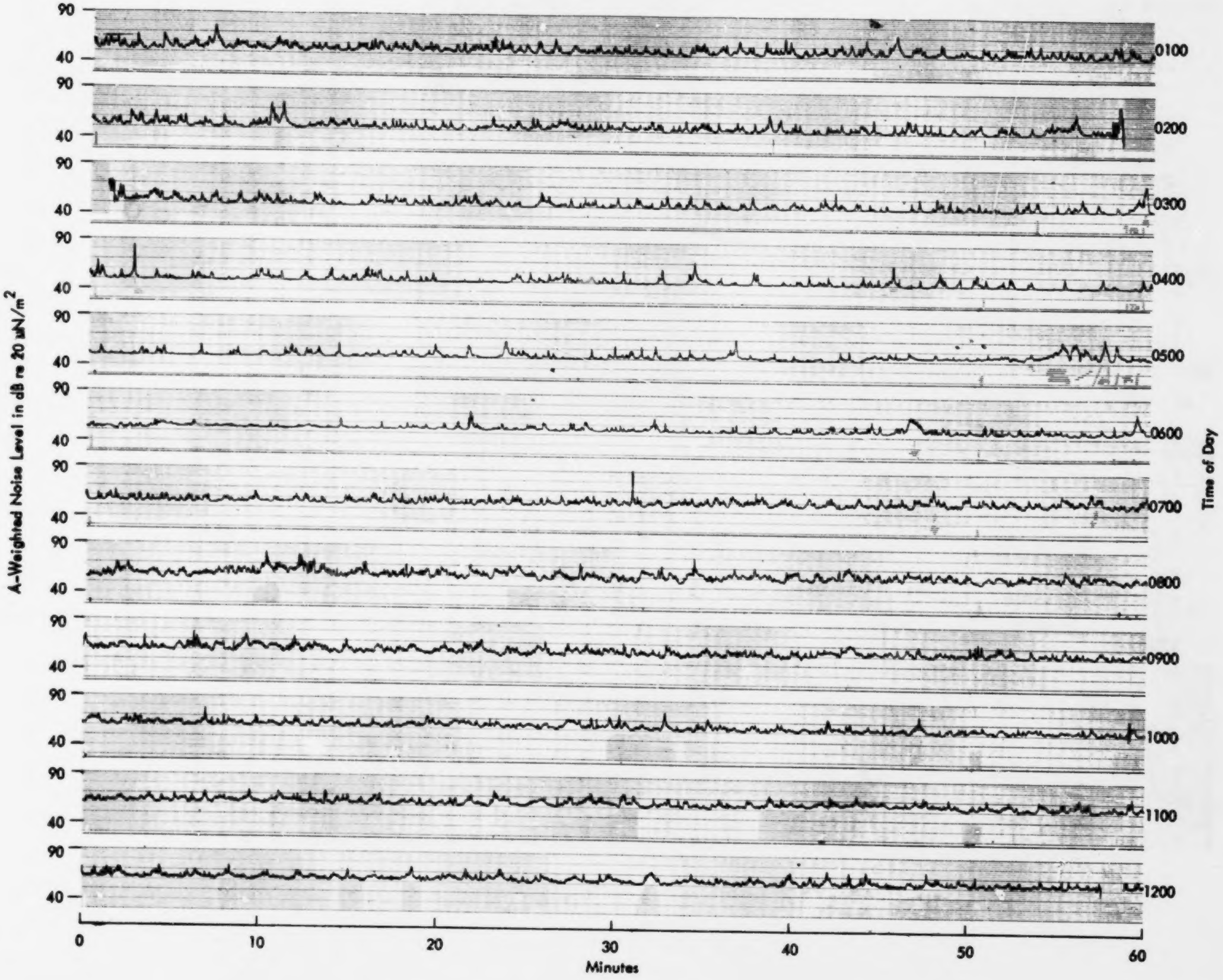
Community Description: Major commercial shopping center; large and small stores, major department stores, high rise office buildings and service stations; 200 feet to Hawthorne Boulevard, a six-lane arterial; 150 feet to Carson, a four-lane arterial; 1.5miles to Pacific Coast Highway, a major four-lane arterial; 2.75 miles to the San Diego Freeway, 3.75 miles to the Harbor Freeway, 1.5 miles to a major small general aviation airport, 1.5 miles to nearest industrial area, and 2.25 miles to a beach.

Noise Environment: Heavy street traffic dominated almost the entire 24-hour period. A store air conditioner vent held up the residual level during the early morning hours. Intruding noises superimposed on the general traffic noises were jet and propeller overflights, trucks, motorcycles, horns, trucks and service equipment for nearby lots and stores. The microphone was located 25 feet above ground, 200 feet from Hawthorne Boulevard, and 150 feet from Carson Boulevard.

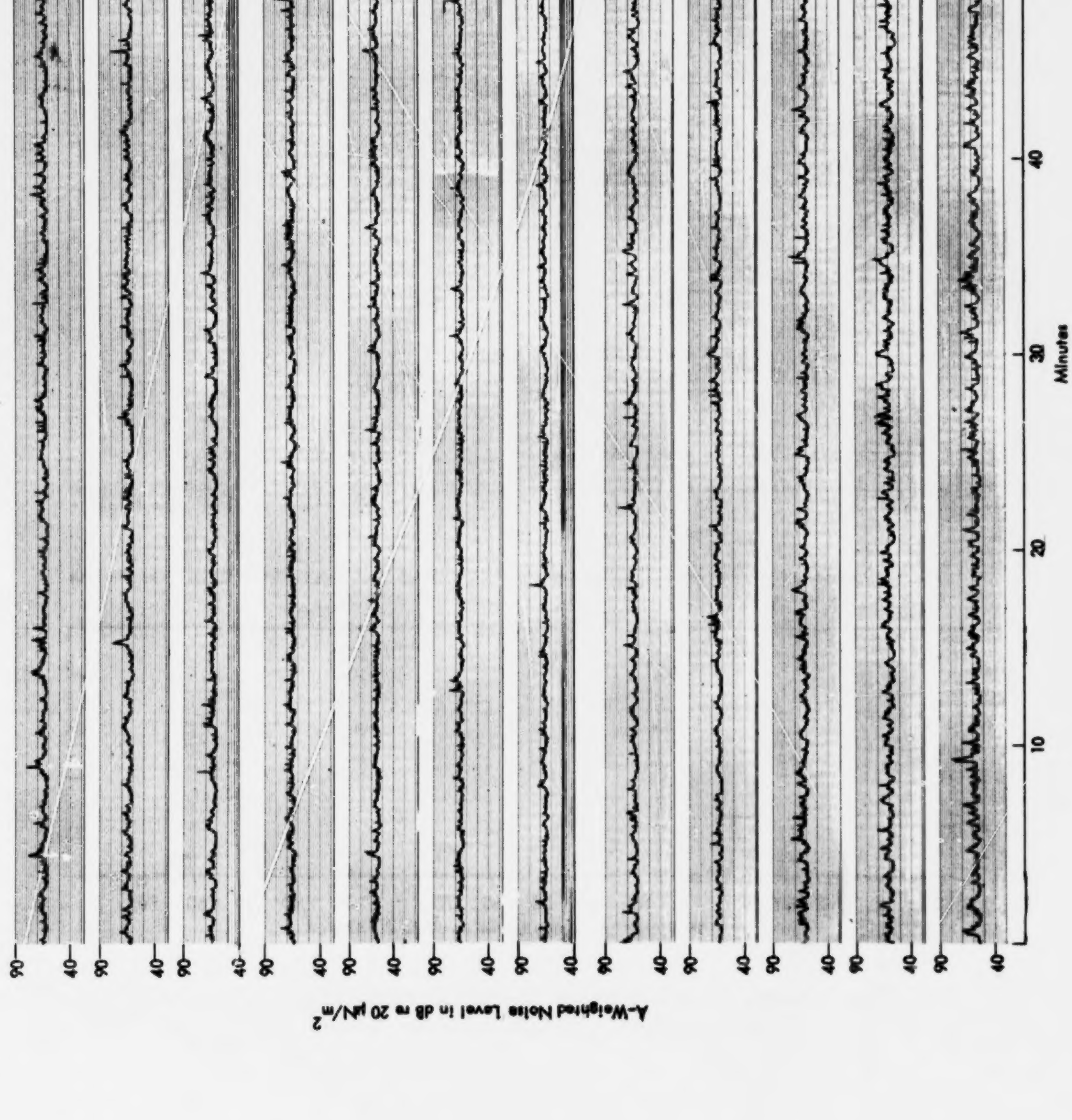
Figure A-4a. Location D – Urban Shopping Center – Torrance, California

Figure A-4b. Time History

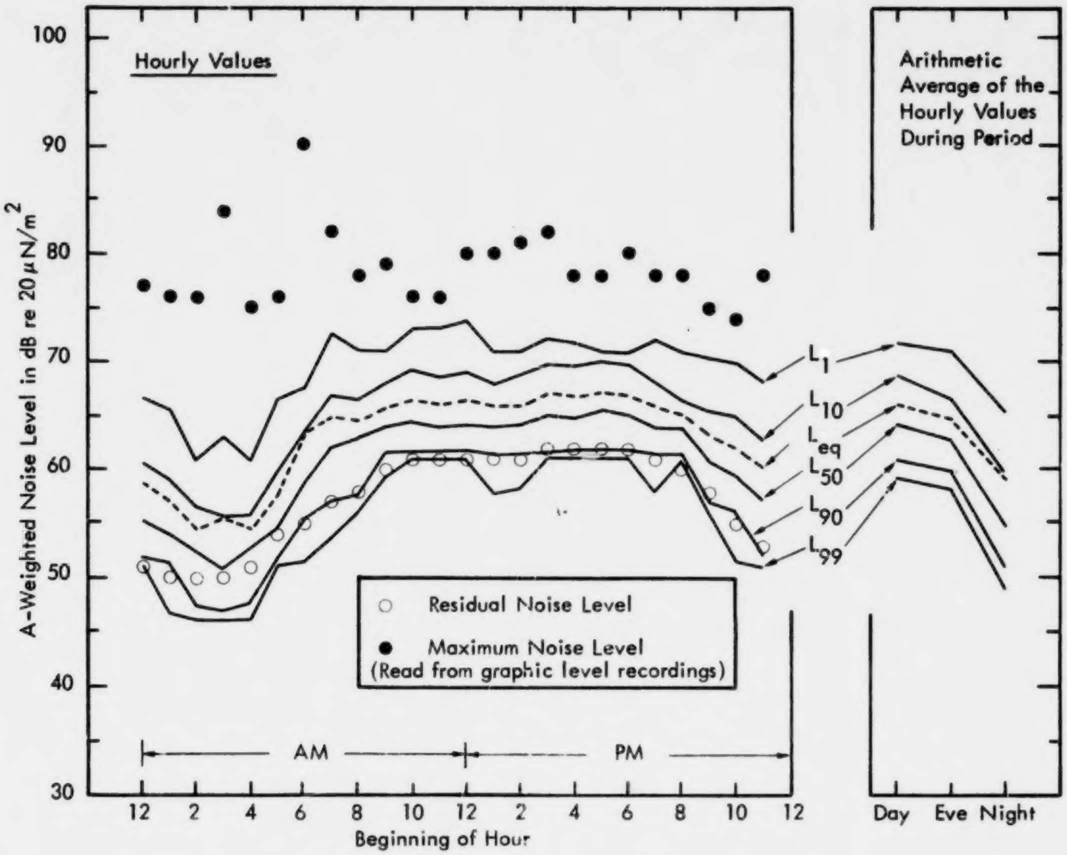
LOCATION D – 0000 Hours to 1200 Hours



LOCATION D – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise Was in Each 5 dB Interval for Three Time Periods

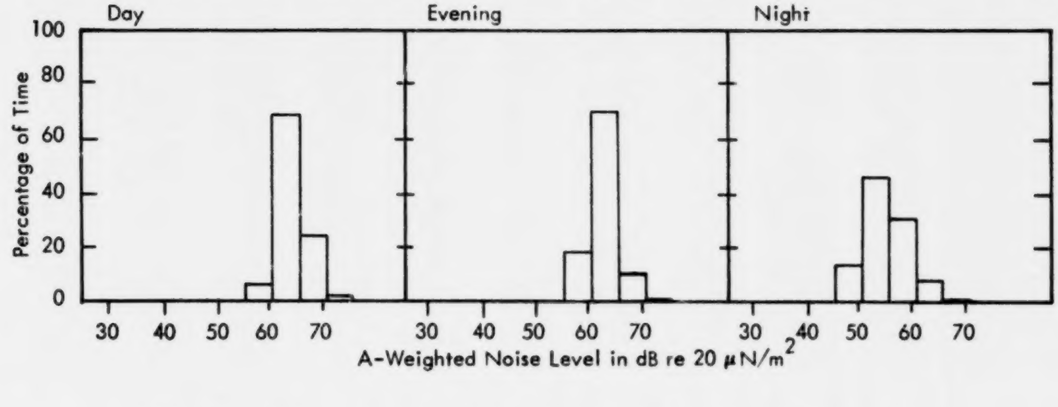
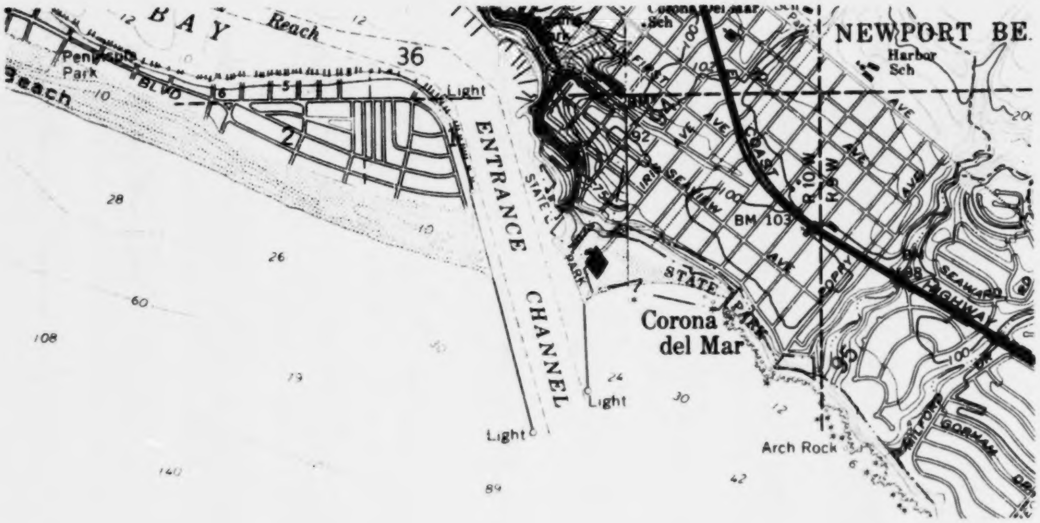


Figure A-4c. Summary of the 24-Hour Outdoor Noise Levels at Location D – Urban Shopping Center


BAY
Beach
36
Peninsula Park
Beach
BLVD
Light
2
ENTRANCE
CHANNEL
STATE PARK
NEWPORT BE
Harbor Sch
BM 103
STATE PARK
Corona del Mar
Light
Light
Arch Rock
SEAWARD
GORMAN

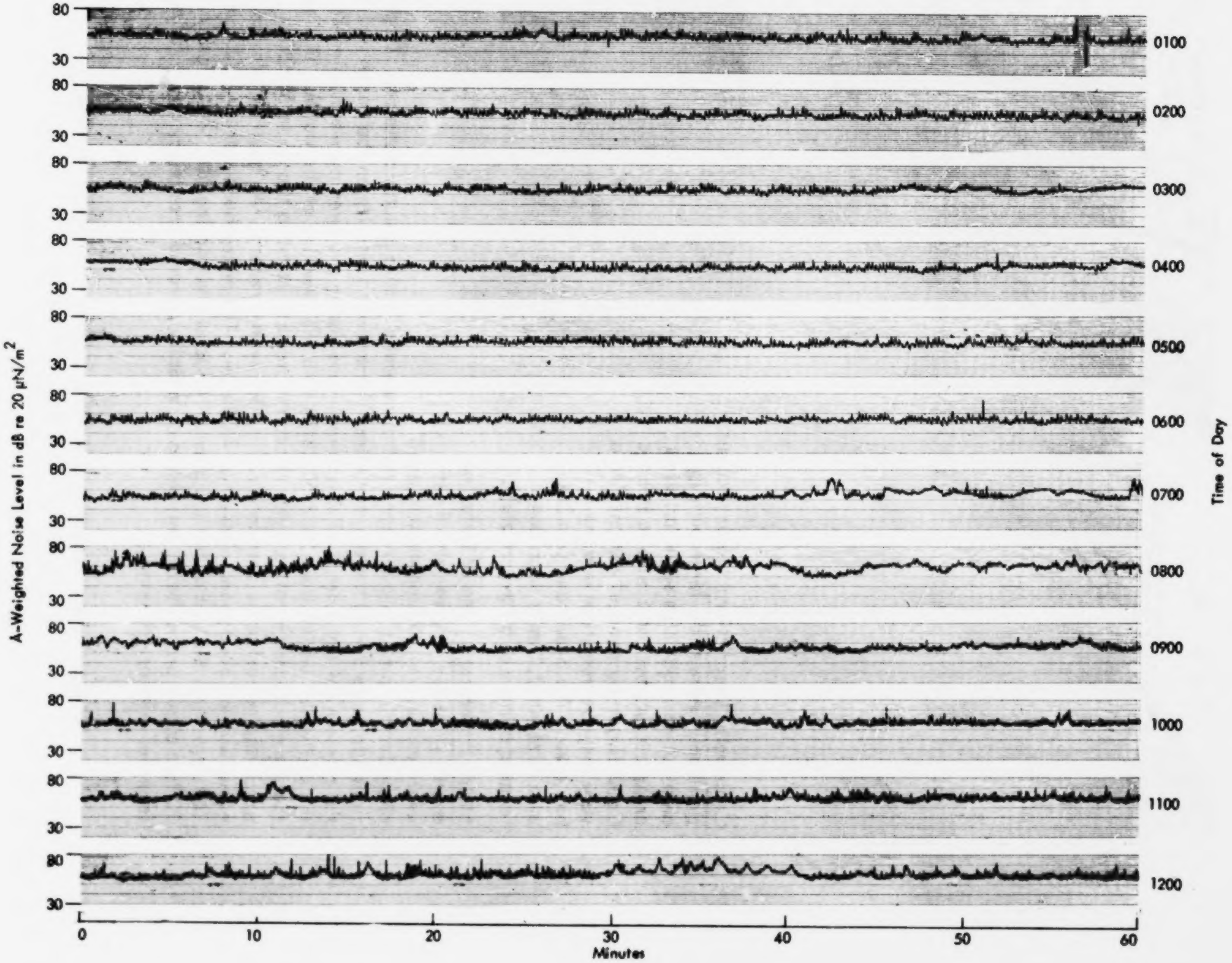
Community Description: Major recreation beach state park; large parking area but no major high speed arterials or streets nearby. 0.5 mile to Pacific Coast Highway; channel entrance to a very large recreational boating and bay area. The beach and parking area is about 0.2 mile wide and located at base of a 75-foot bluff.

Noise Environment: Major intruding events were due to a variety of air vehicles; several helicopters and small propeller aircraft at close range, and commercial jets at greater distances. Considerable noise during the day came from recreational activity on the beach and in the refreshment stand area. The residual noise during the evening was dominated by the surf which varied from 50 to 60 dB(A) with the breaking of the waves. During the day the recreational activity raised the residual level to the 56 to 58 dB(A) range and no surf noise pattern is noticeable on the record. An unusual intruding event was the beach sand cleaner at 7:30 a.m. The microphone was located about 100 yards from the surf at the junction of the sand and parking lot. It was placed 20 feet above ground level and above a partially covered breezeway about 75 feet from the refreshment stand.

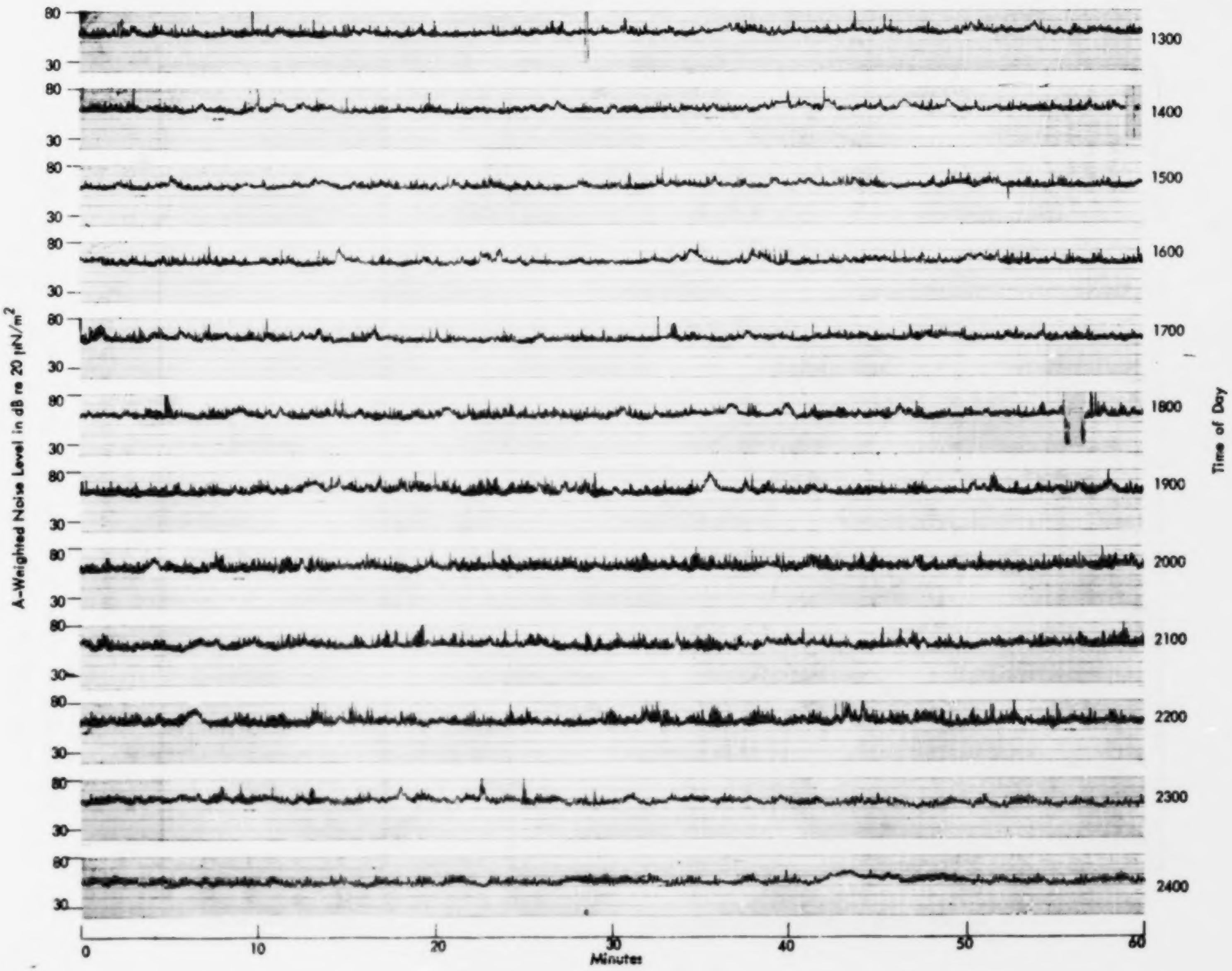
Figure A-5a. Location E – Popular Beach on Pacific Ocean – Corona Del Mar, California

Figure A-5b. Time History

LOCATION E – 0000 Hours to 1200 Hours



LOCATION E – 1200 Hours to 2400 Hours



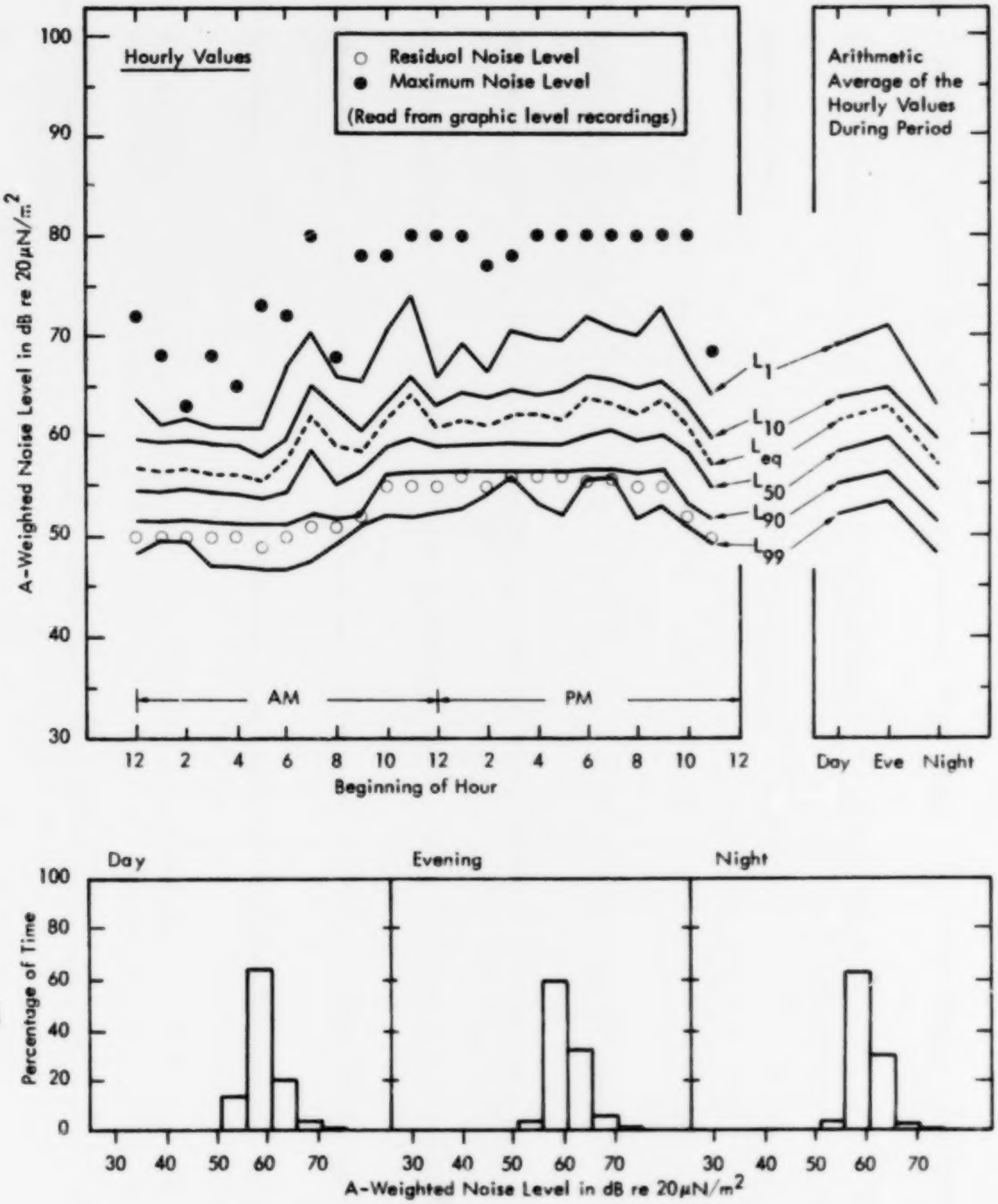
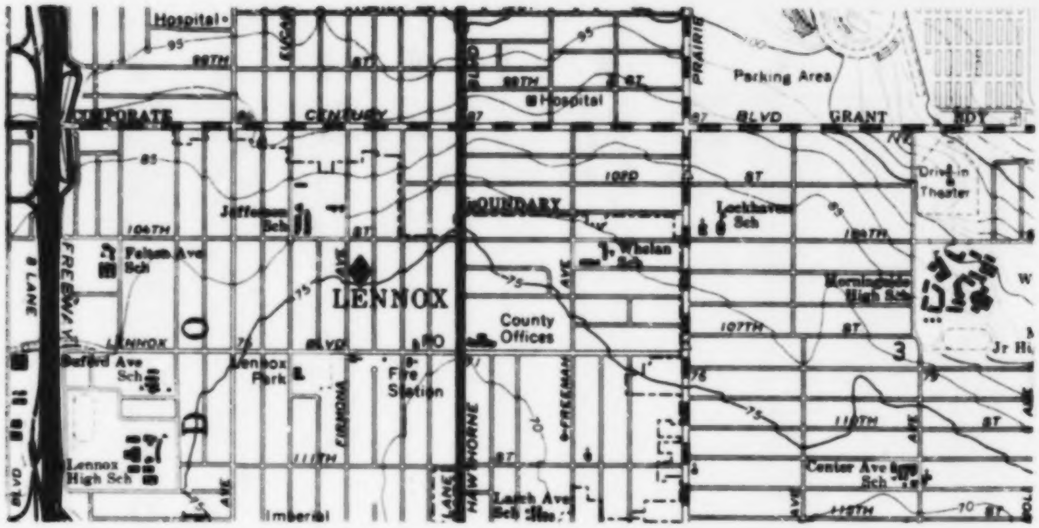


Figure A-5c. Summary of the 24-Hour Outdoor Noise Levels at Location E – Popular Beach on Pacific Ocean


Hospital
CORPORATE
CENTURY
BLVD
GRANT
Parking Area
Hospital
Drive in Theater
104TH
BOUNDARY
Jefferson Sch
Lockhaven Sch
Felton Ave Sch
Whelan Sch
LENNOX
County Offices
Morningside High Sch
107TH
LENNOX
BLVD
Buford Ave Sch
Lennox Park
Fire Station
Lennox High Sch
FREEWAY
8 LANE
HAWTHORNE
FIRMONA
FREEMAN
Imperial
111TH
Lamb Ave Sch
Center Ave Sch
PRAIRIE
Jr Hi
75
85
95
100

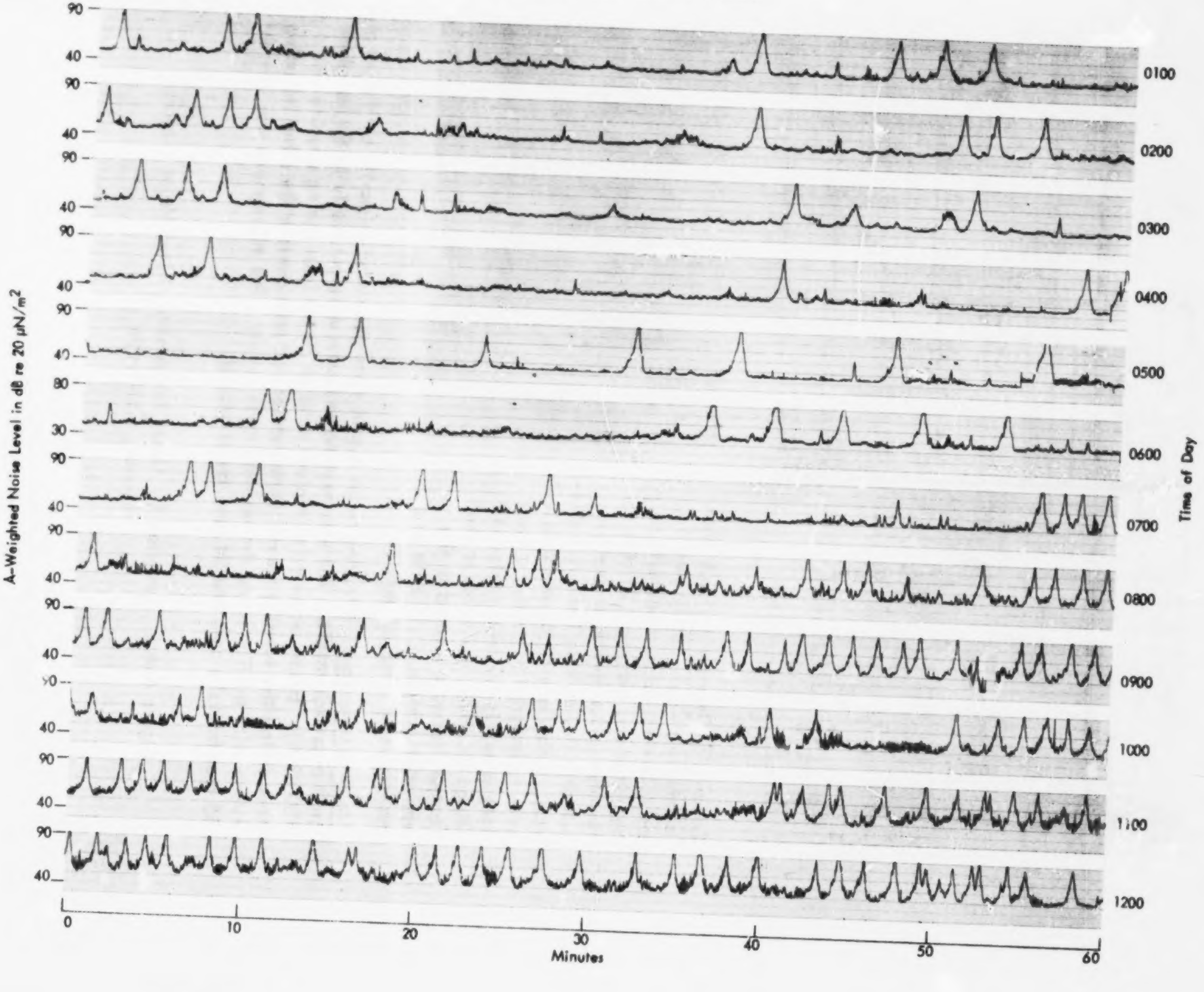
Community Description: Suburban residential; single family dwellings only; 36-foot-wide street with only neighborhood traffic; 0.25 mile to Hawthorne Boulevard, a six-lane arterial; 0.3 mile to Century Boulevard, a six-lane major arterial; 0.7 mile to Imperial Highway, a four-lane arterial; 0.7 mile to the San Diego Freeway, 4.4 miles to the Harbor Freeway; located in the approach pattern, 0.75 mile to a major metropolitan airport.

Noise Environment: Intruding noise events were generated primarily by the jet aircraft approach traffic. The maximum noise levels were generally in the range of 100 dB(A). Events occurred at typical rates of 30 per hour during daytime and 6 per hour during the morning hours. Automobiles and dogs created the other intruding events with traffic setting the residual noise levels. The microphone was located 55 feet from the curb and 24 feet above ground.

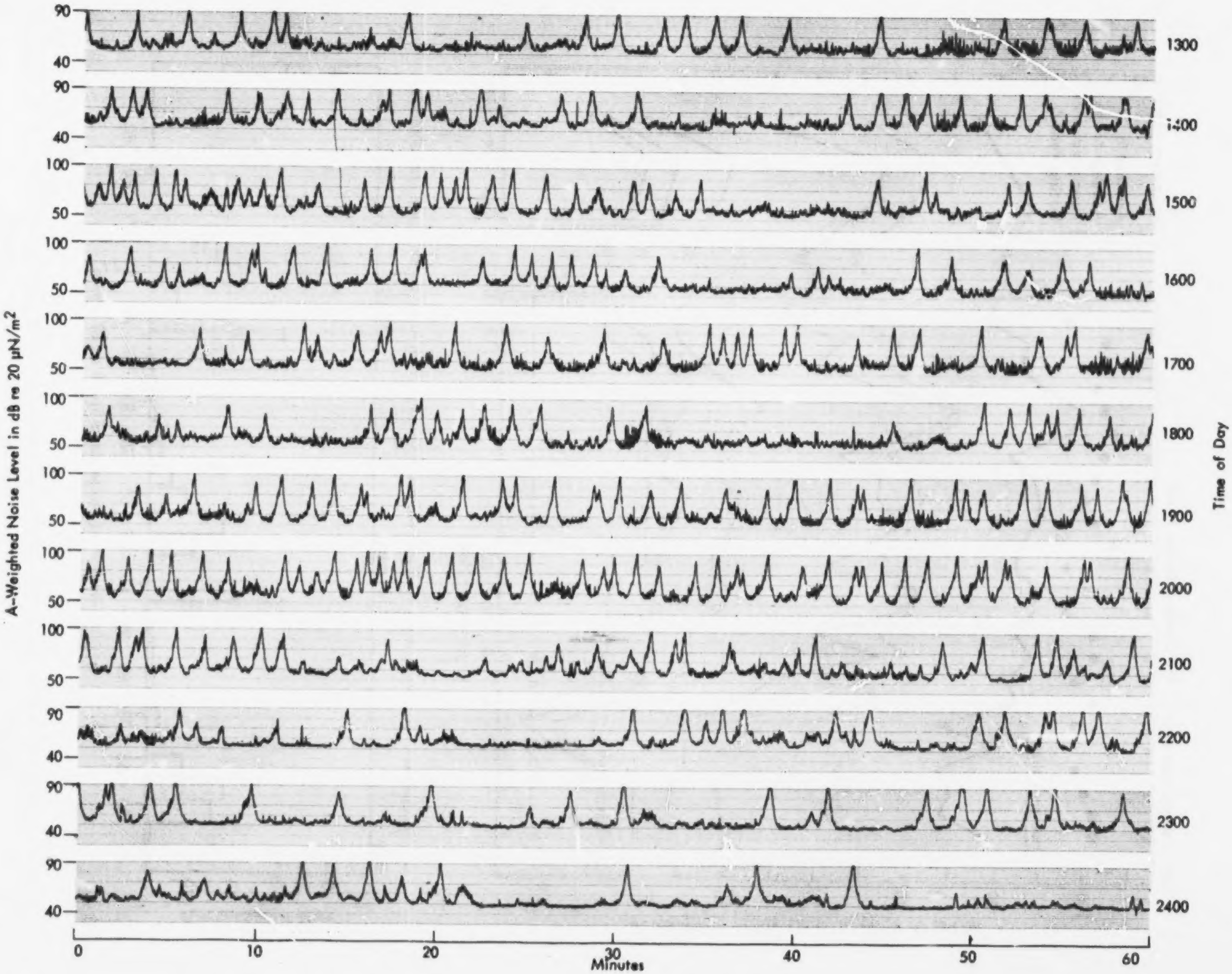
Figure A-6a. Location F – Urban Residential, Near Major Airport – Lennox, California

Figure A-6b. Time History

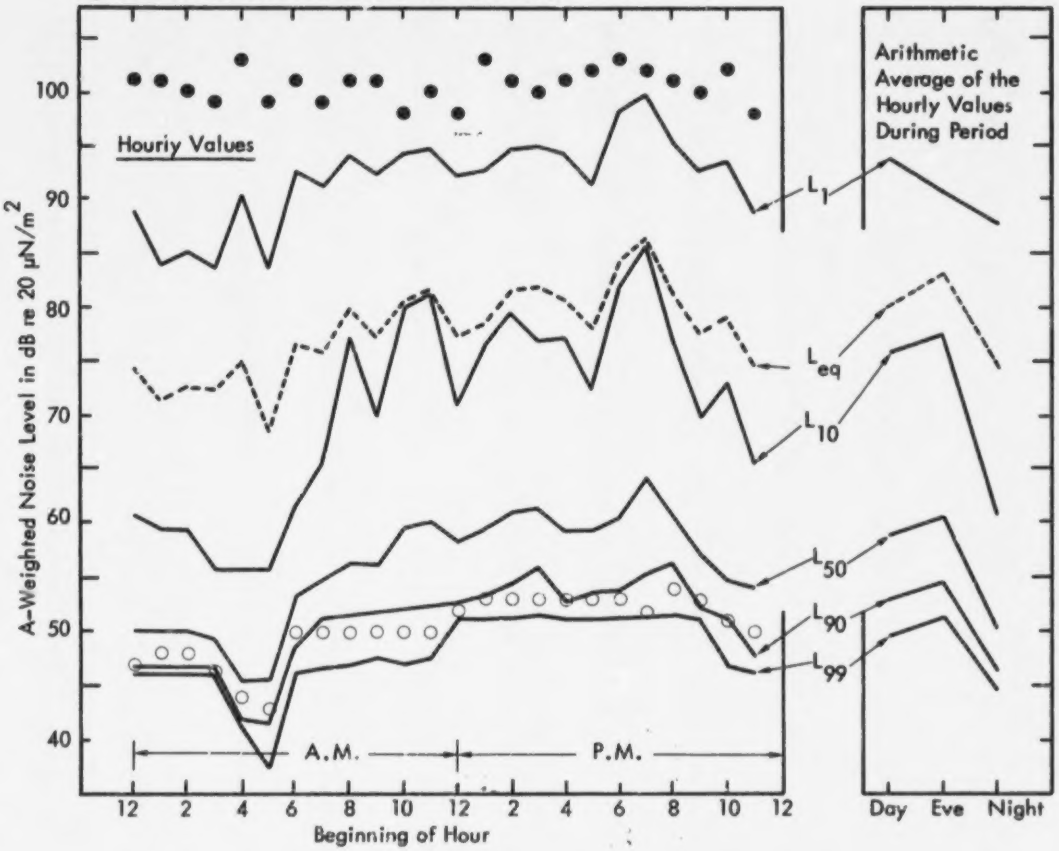
LOCATION F – 0000 Hours to 1200 Hours



LOCATION F – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise was in Each 5 dB Interval for Three Time Periods

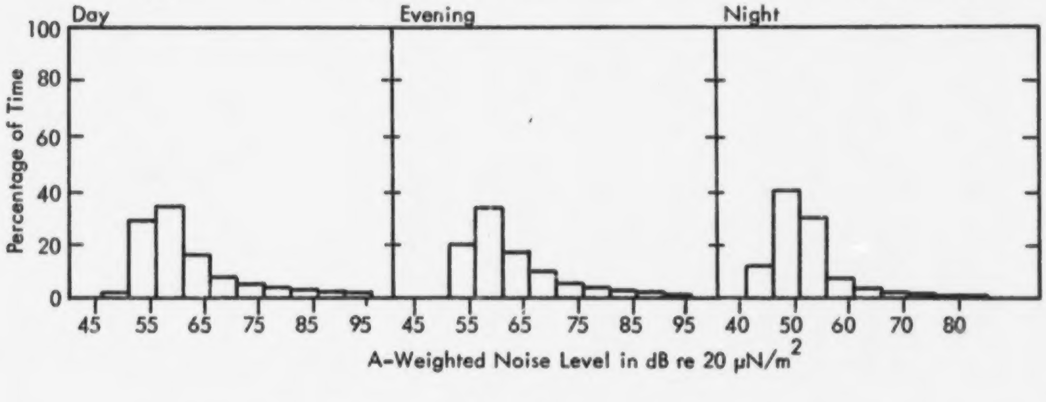
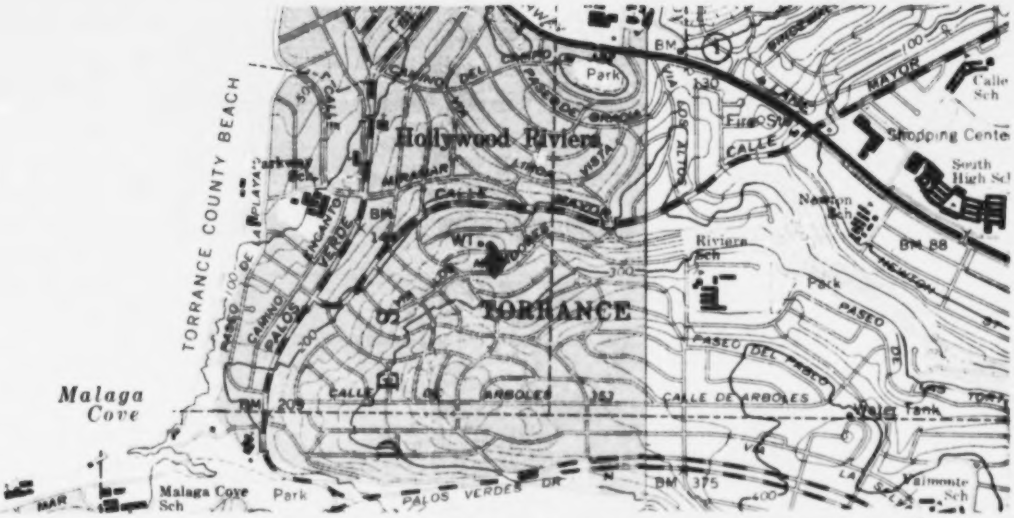


Figure A-6c. Summary of the 24-Hour Outdoor Noise Levels at Location F – Urban Residential, Near Major Airport


TORRANCE COUNTY BEACH
Malaga Cove
Hollywood Riviera
TORRANCE
Park
Shopping Center
South High Sch
Riviera Sch
Malaga Cove Sch
PALOS VERDES DR
CALLE DE ARBOLES
Calle Sch
Newton Sch
Valmonte Sch
Tank

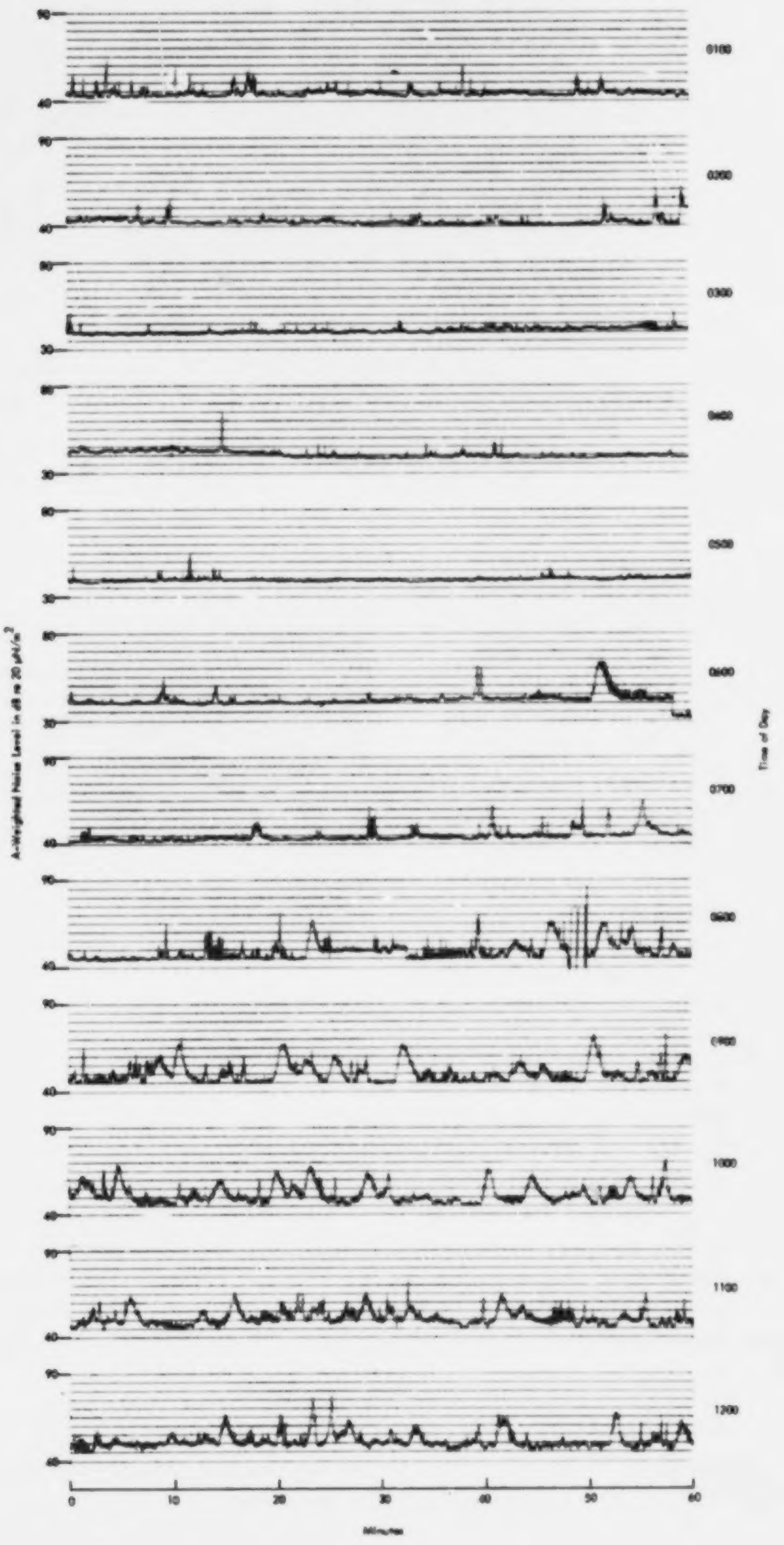
Community Description: Suburban residential; single family dwellings only; 22 foot wide street, 2 blocks long; only traffic local to the dwellings on the street; 0.3 mile to Palos Verdes, a four-lane arterial; 0.5 mile to Pacific Coast Highway, a major four-lane arterial; 4.5 miles to San Diego Freeway, 5.5 miles to the Harbor Freeway, 2 miles to major general aviation airport, 2 miles to major shopping and financial district; 4 miles to nearest industrial area; and 0.6 miles to beach.

Noise Environment: The major intruding noises were from single engine aircraft from the nearby general aviation airport and from jet overflights from a major metropolitan airport. Background traffic from adjoining streets and arterials, sirens, children on the street, delivery and service trucks formed the other intruding sources. Residual noise levels were dominated by urban traffic. A water company diesel generator across the street increased the residual level by 5 dB(A) for 3 hours during the early evening. A street sweeper, motorcycle, helicopter, and a neighbor hooking up a trailer were the unusual single events for the 24-hour period. The microphone was located 40 feet from the curb and 20 feet above street level. The 24-hour noise level charts for this location were produced on a different chart paper than that used at the other 17 sites.

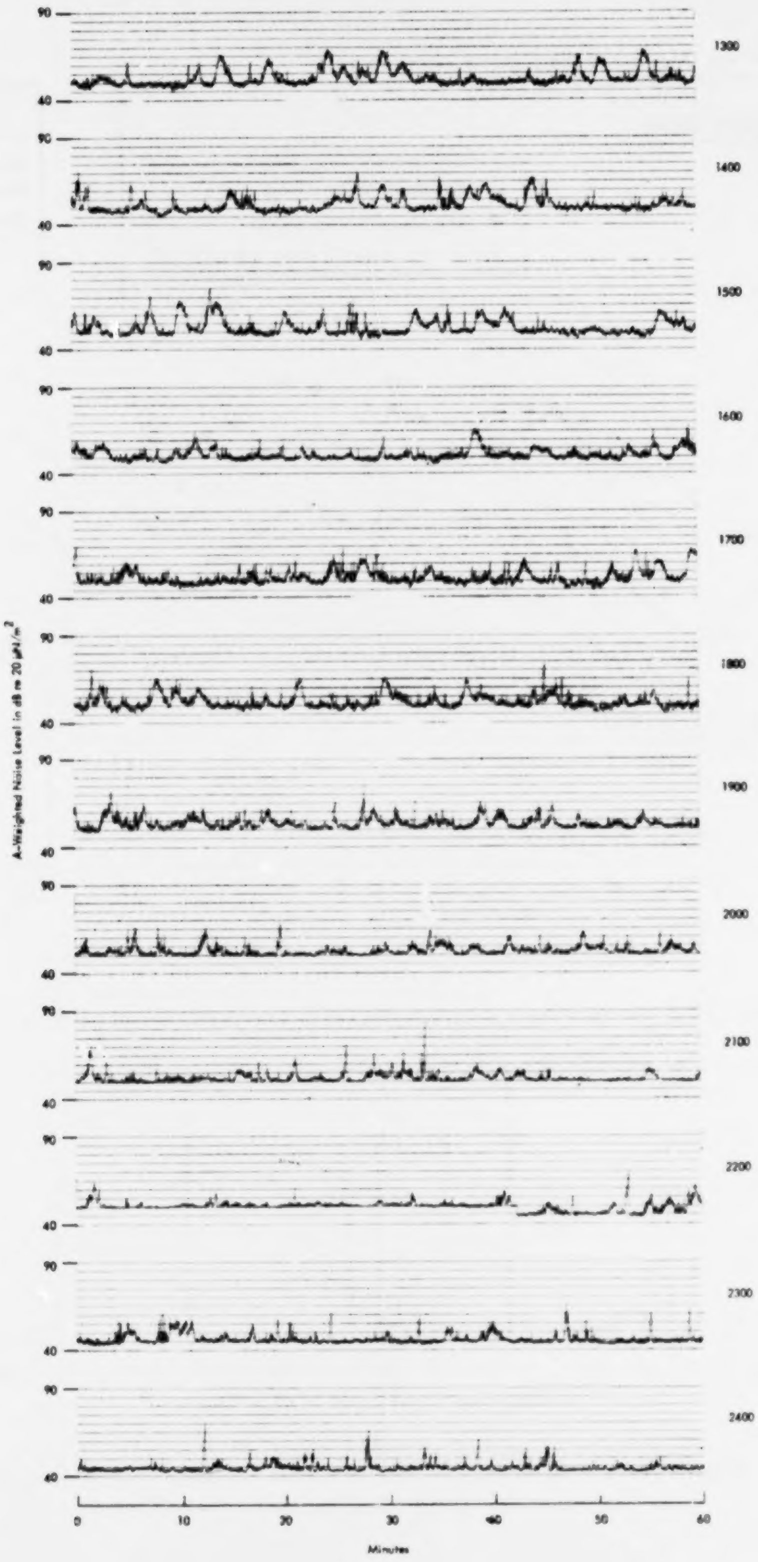
Figure A-7a. Location G – Urban Residential, Near Ocean – Redondo Beach, California

Figure A-7b. Time History

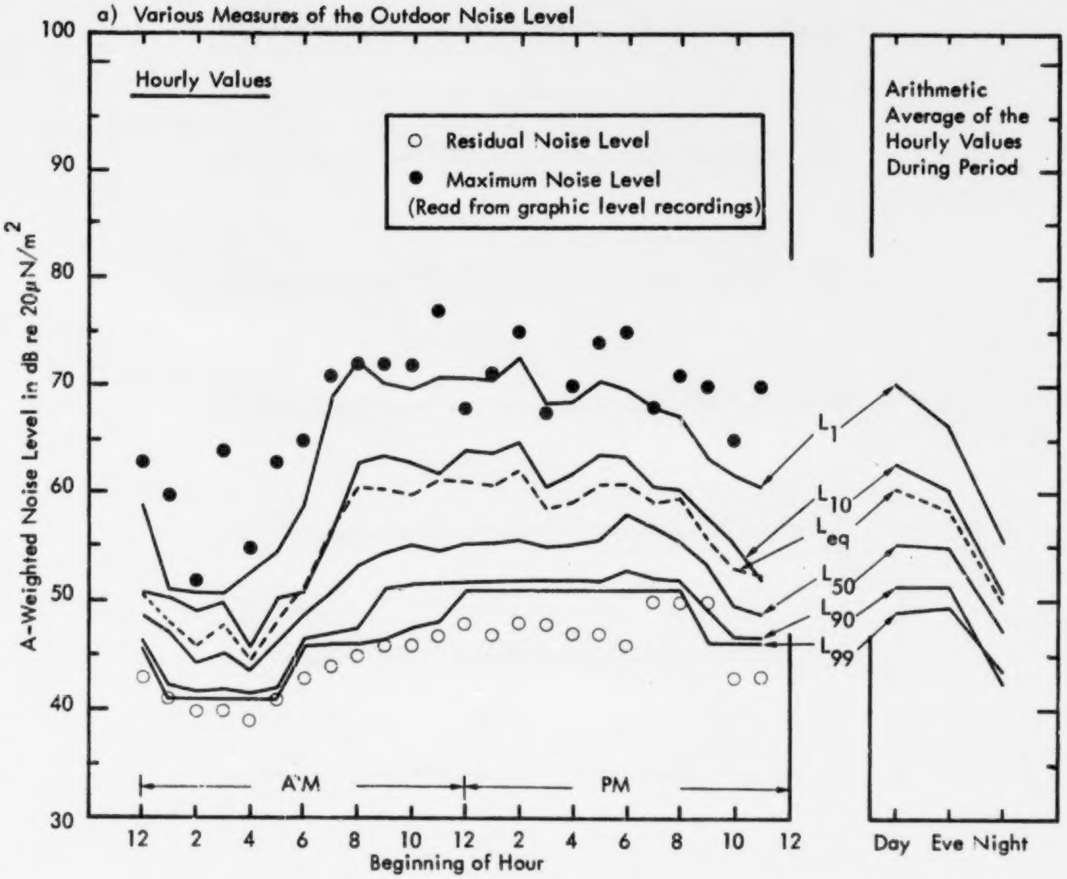
LOCATION G – 0000 Hours to 1200 Hours



LOCATION G – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise was in Each 5 dB Interval for Three Time Periods

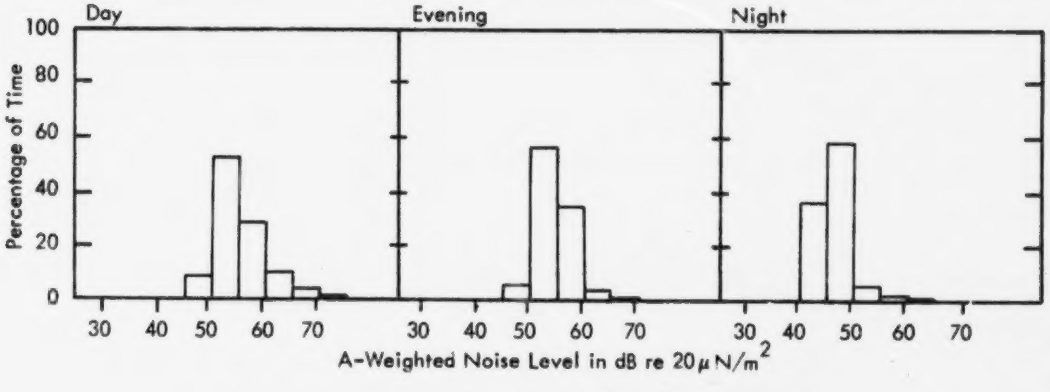
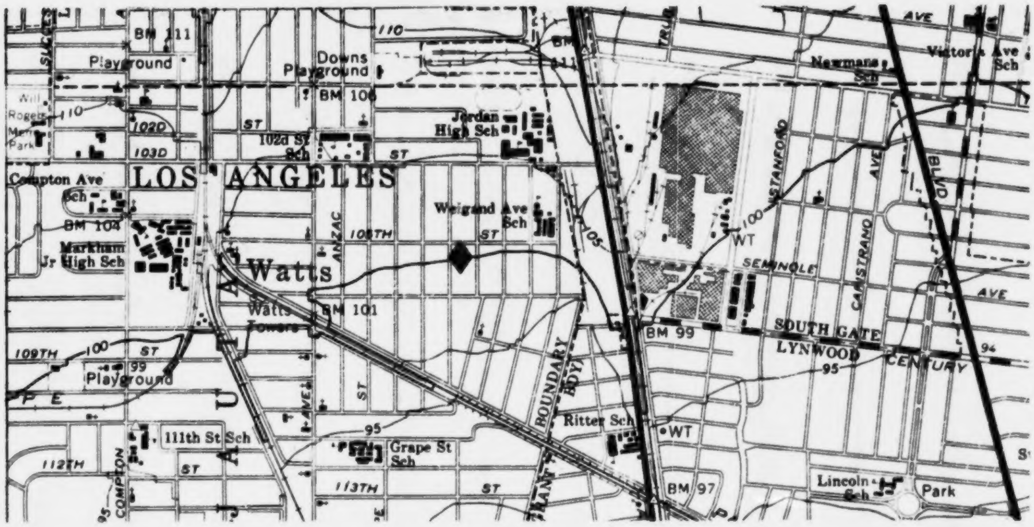


Figure A-7c. Summary of the 24-Hour Outdoor Noise Levels at Location G – Urban Residential, Near Ocean


BM 111
Playground
Downs
Playground
BM 106
Will Rogers Mem Park
102D
103D
102d St Sch
Jordan High Sch
Compton Ave Sch
LOS ANGELES
BM 104
Markham Jr High Sch
Watts
Weigand Ave Sch
108TH
ST
ANZAC
Watts Towers
BM 101
109TH
ST
99
Playground
111th St Sch
Grape St Sch
112TH
ST
113TH
ST
COMPTON
BOUNDARY
Ritter Sch
WT
BM 99
BM 97
SEMINOLE
STANFORD
CAPISTRANO
AVE
BLVD
SOUTH GATE
LYNWOOD
CENTURY
95
100
110
Newmans Sch
Victoria Ave Sch
Lincoln Sch
Park

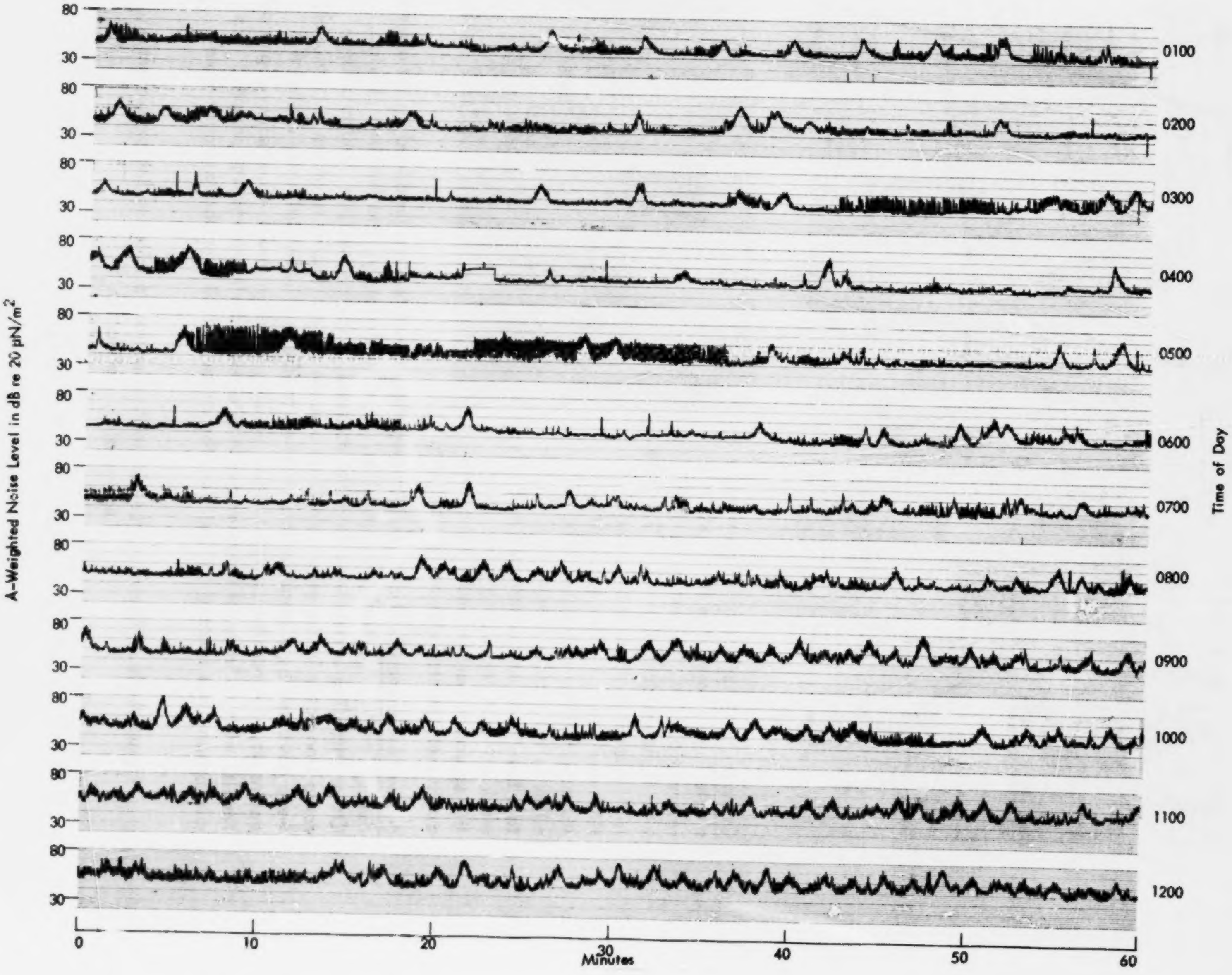
Community Description: High density single family dwellings in an urban residential area, 34 feet wide street with light residential traffic, 0.3 mile to Alameda; 0.75 mile to Imperial Highway and 1.2 miles to Central Avenue, all four-lane arterials; 2.7 miles to the Harbor Freeway, 0.3 mile to a heavy industrial area and multiple track railroad and siding yard; under the approach pattern and 8 miles to a major metropolitan commercial airport.

Noise Environment: The major intruding single events were produced by jet aircraft during landing approach, automobiles, dogs, helicopters, and children playing. Other intruding events were from the railroad, a factory whistle, and two large scrap iron yards in the area. Residual sources were difficult to assess but probably were governed by a combination of urban traffic and industrial noise during the entire day. Aircraft overflights were of long duration and at moderately high noise levels, with no interval between event thresholds during the busier periods. The microphone was located 50 feet from the street and 20 feet above ground level.

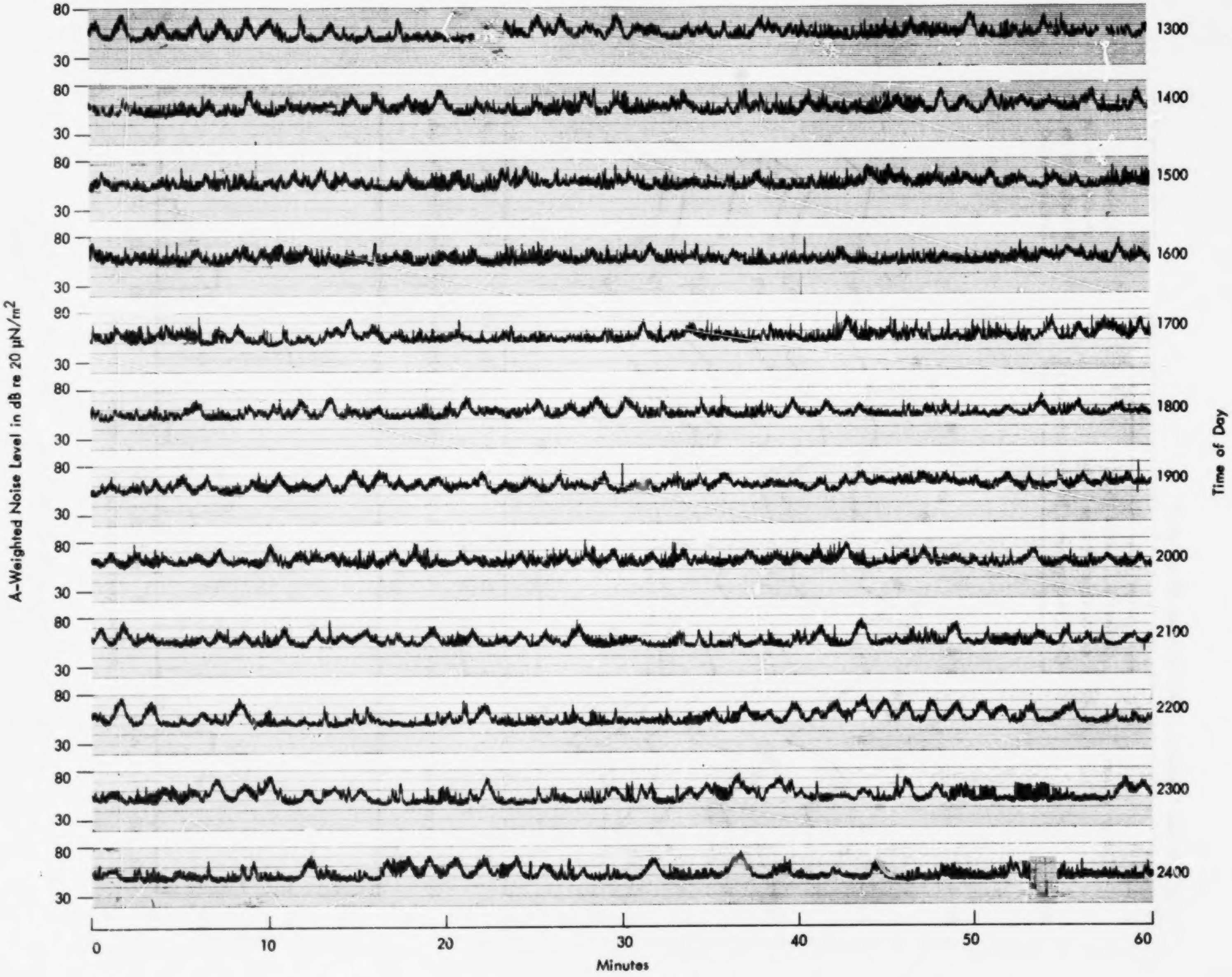
Figure A-8a. Location H – Urban Residential, 6 miles to Major Airport – Los Angeles, California

Figure A-8b. Time History

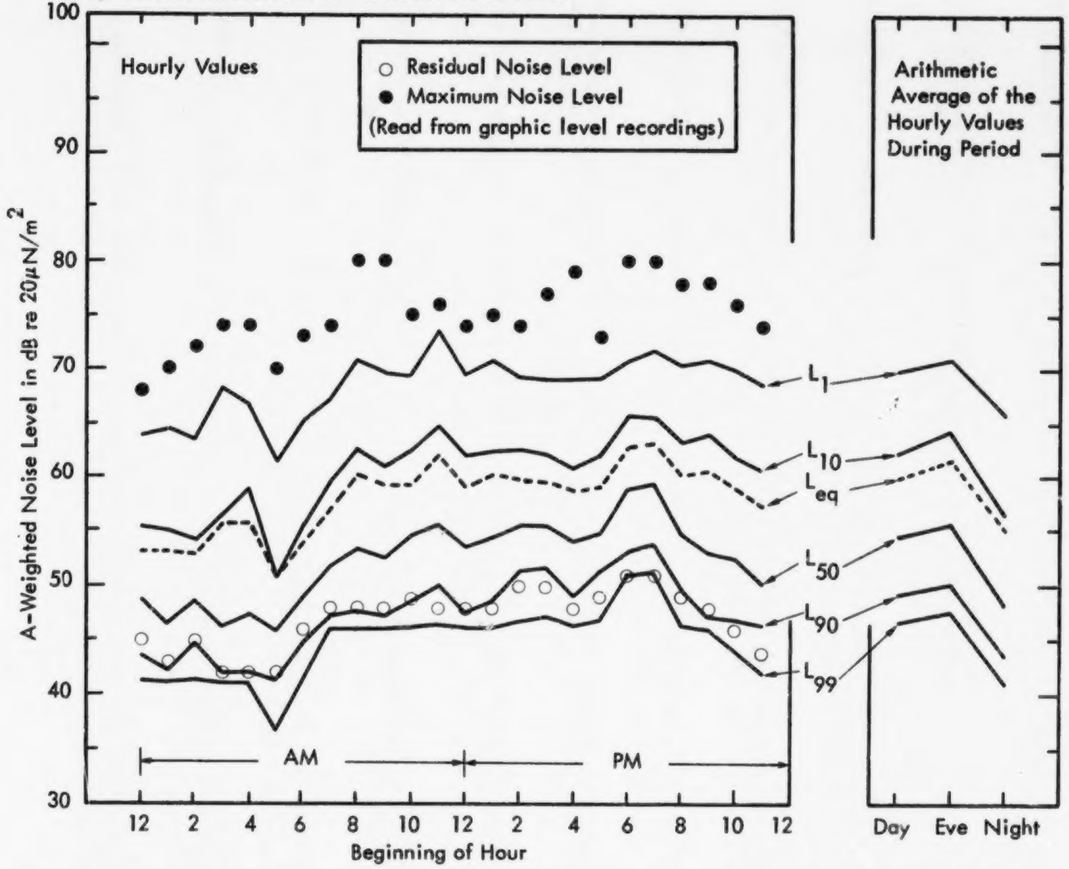
LOCATION H – 0000 Hours to 1200 Hours



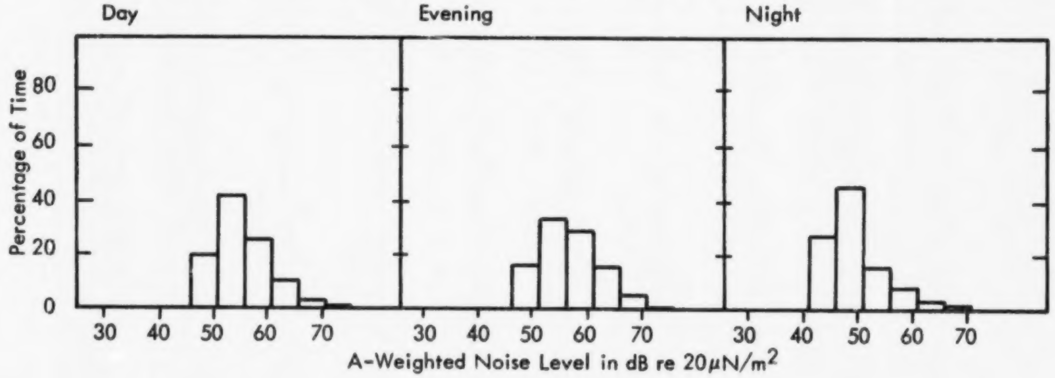
LOCATION H – 1200 Hours to 2400 Hours



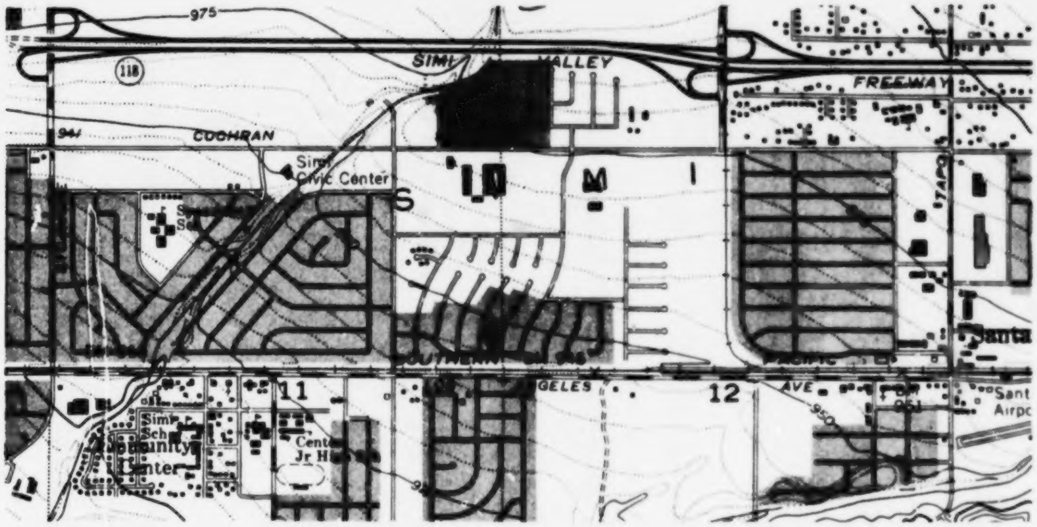
a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise Was in Each 5 dB Interval for Three Time Periods



igure A-8c. Summary of the 24-Hour Outdoor Noise Levels at Location H – Urban Residential, 6 Miles to Major Airport


975
118
SIMI VALLEY
FREEWAY
COCHRAN
Simi Civic Center
SIMI
TAPO
Santa
SOUTHERN PACIFIC
LOS ANGELES AVE
11
12
Simi Sch
Community Center
Central Jr High
Santa Susana Airport

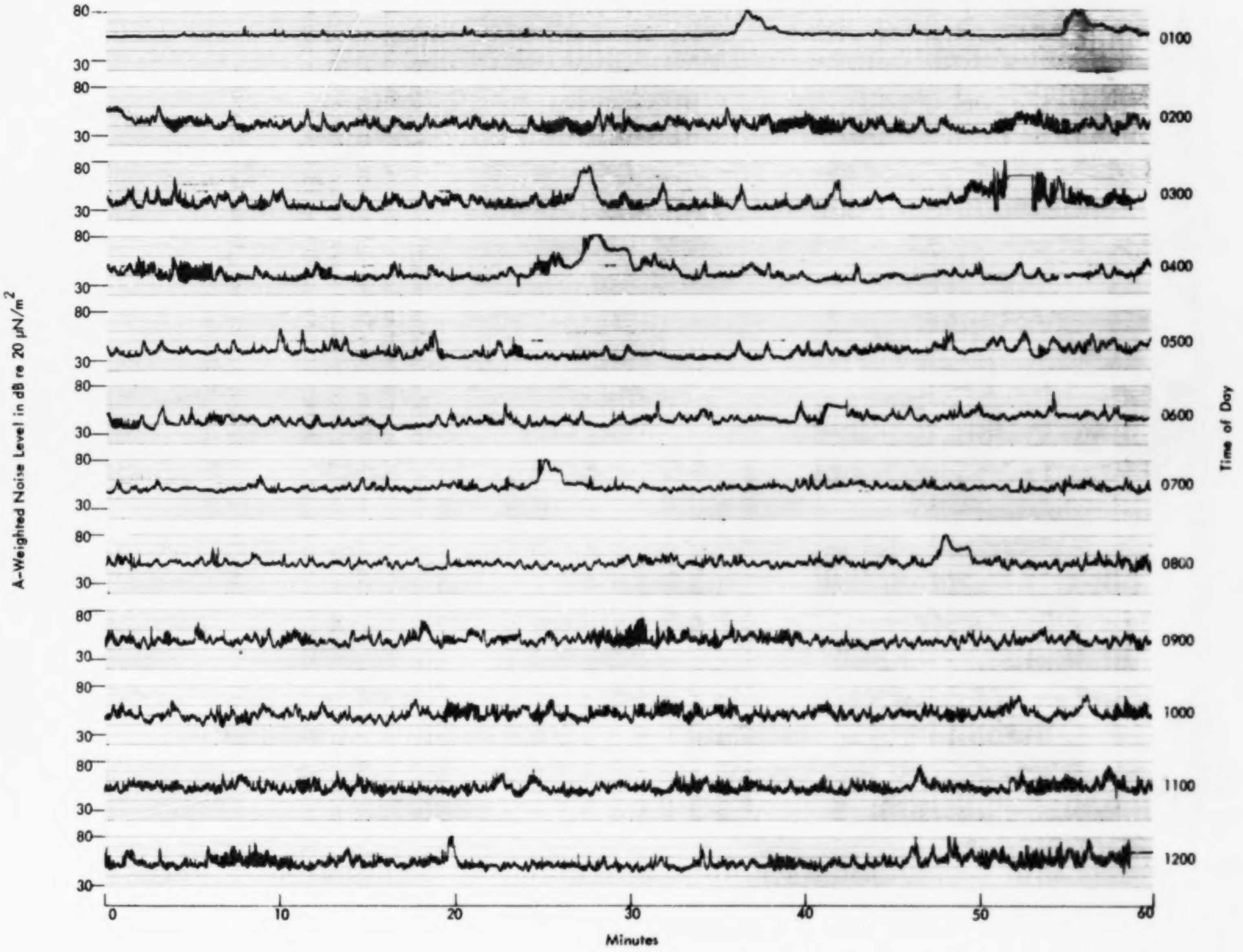
Community Description: Suburban residential at the outskirts of a large metropolitan area; 36-foot wide street serving only neighborhood traffic; 350 feet to Los Angeles Avenue, a four-lane major arterial; 0.7 mile to the Simi Freeway; 300 feet to the Southern Pacific Railroad track, 0.6 mile to light commercial and business district, 1.0 mile to a small aircraft landing strip.

Noise Environment: Major intruding noise events were produced by trains, small airplane overflights, and automobiles. Other intruding noises were produced by dogs and an ice cream vendor, motorcycles, children playing, and a rocket test burst from the Santa Susana rocket test stand area. Minimum noise levels during the midnight hour were set by a train idling on a siding. The microphone was located 50 feet from the curb and 18 feet above ground.

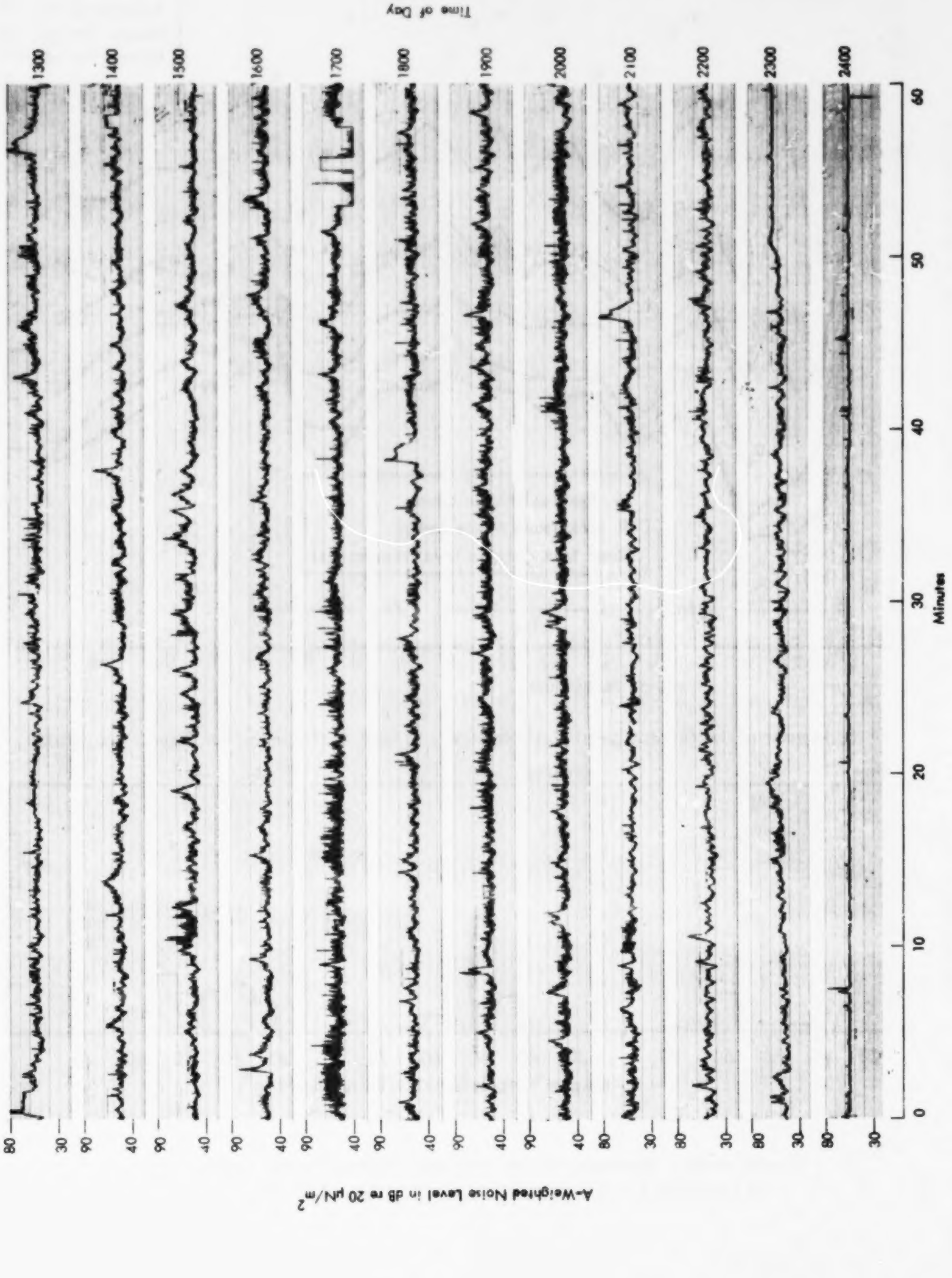
Figure A-9a. Location I – Suburban Residential, Near R/R Tracks - Simi Valley, California

Figure A-9b. Time History

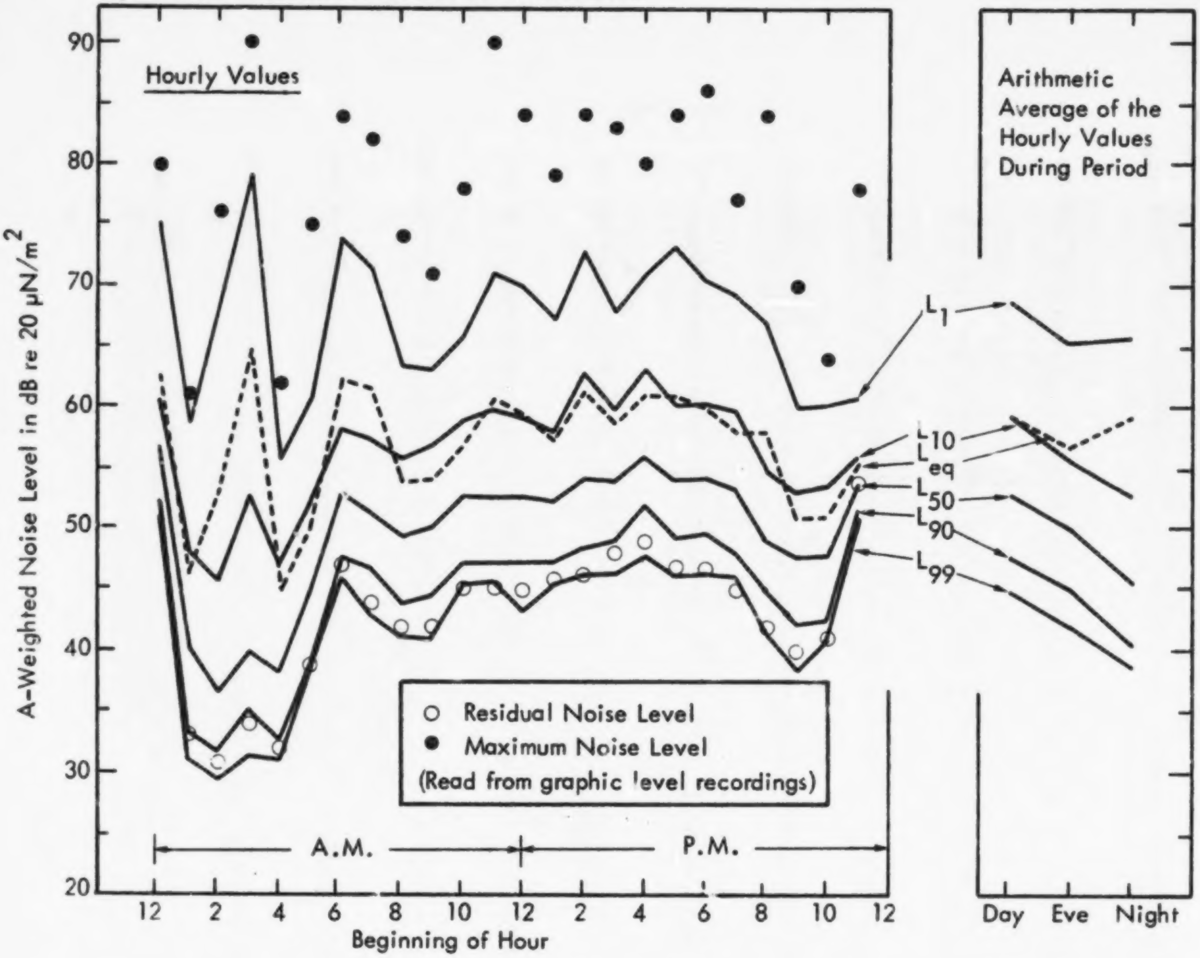
LOCATION I – 0000 Hours to 1200 Hours



LOCATION I – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise was in Each 5 dB Interval for Three Time Periods

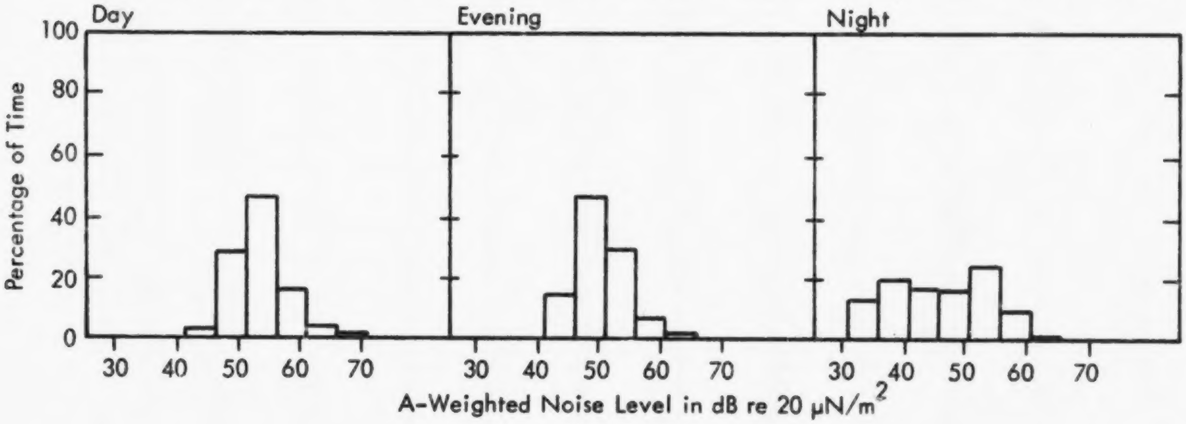
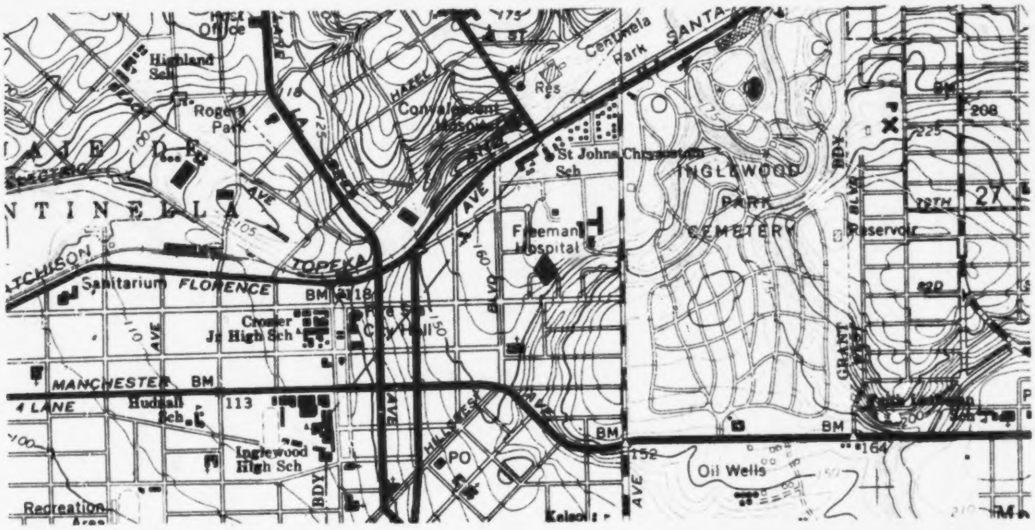


Figure A-9c. Summary of the 24-Hour Outdoor Noise Levels at Location I – Suburban Residential, Near R/R Tracks


Highland Sch
Rogers Park
Convalescent Hospital
Res
Centinela Park
SANTA
St Johns Chrysostom Sch
INGLEWOOD PARK CEMETERY
Reservoir
Freeman Hospital
TOPEKA
Sanitarium
FLORENCE
BM
118
Crozier Jr High Sch
City Hall
MANCHESTER
BM
4 LANE
Hudnall Sch
113
Inglewood High Sch
PO
BM
152
Oil Wells
BM
164
GRANT
Recreation Area
Kelso
208
225
27
AVE
BLVD
BDY

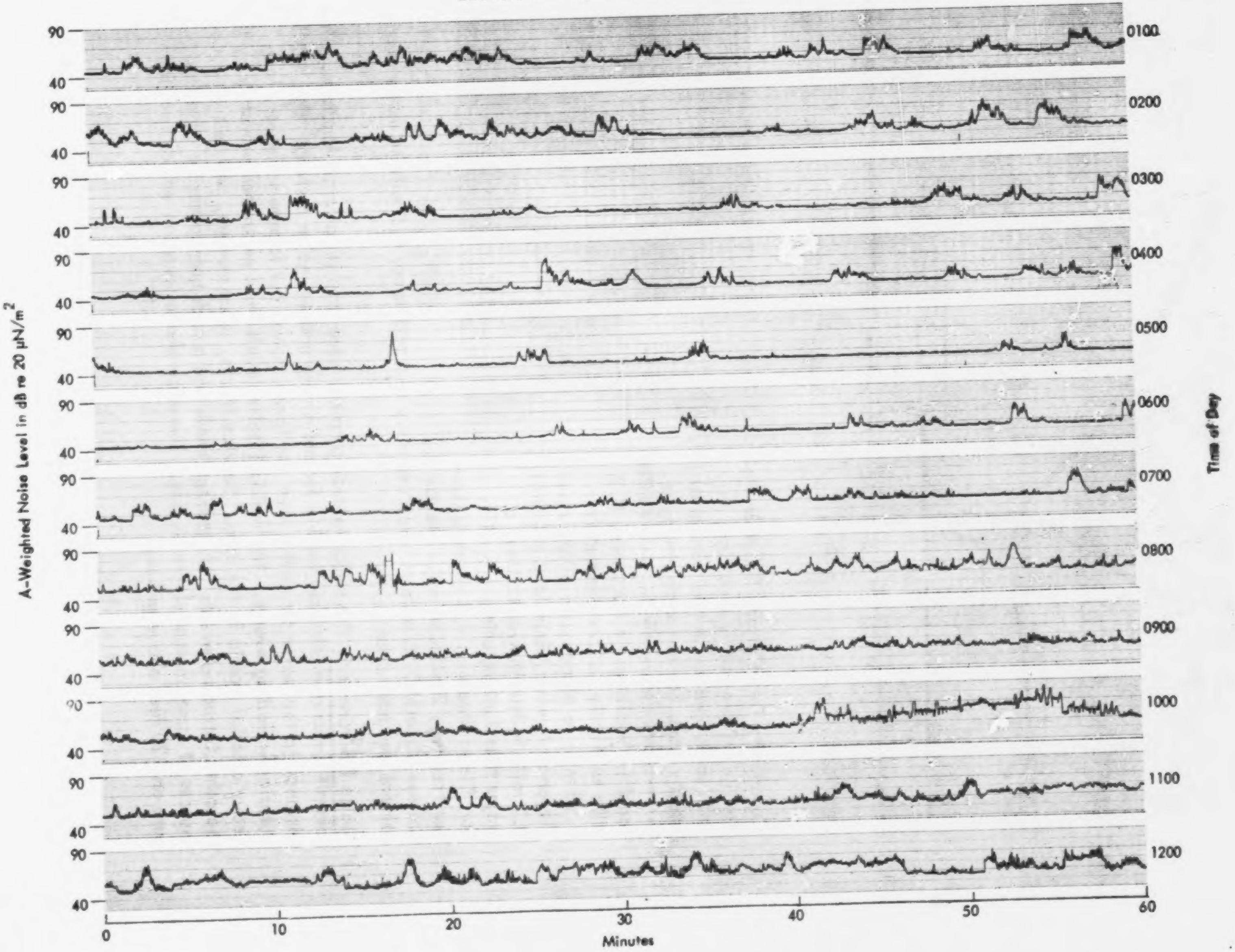
Community Description: Suburban residential; single family dwellings only with some apartments and a hospital in nearby area; 36-foot wide street, a three-block closed circle; only traffic local to dwellings on the street; 0.2 mile to Prairie, a four-lane street, 0.25 mile to Manchester Avenue and Florence Avenue, four-lane arterials; 0.3 mile to Hawthorne-LaBrea, a major four-lane arterial; 1.3 miles to San Diego Freeway; 3.8 miles to Harbor Freeway; 2 miles to major metropolitan airport; 0.25 mile to large cemetery and park area; 0.5 mile to major recreational and park area.

Noise Environment: The major intruding noises were from jet aircraft landings. The takeoff runup and climbout rumble formed a very unusual noise pattern. The sideline distance to the major air traffic kept the levels down, but formed some very long duration intruding events. The residual noise levels were generated primarily by the heavy arterial traffic in the area. Service trucks, lawn mowers, and cars produced the other intruding events. A garbage truck and a rock band practice were the sources of some unusual single events. The microphone location was 40 feet from curb and 20 feet above ground.

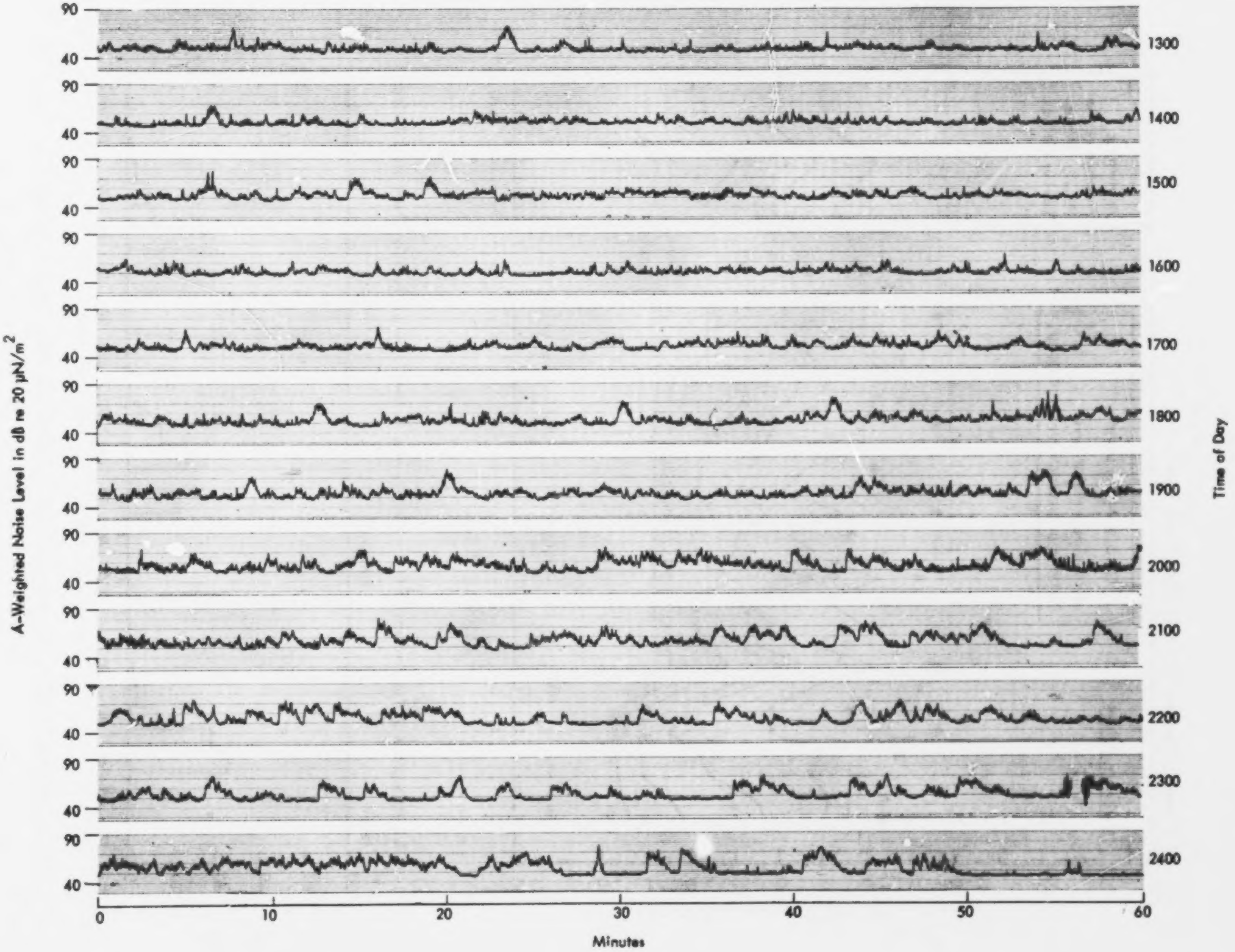
Figure A-10a. Location J – Urban Residential –
Inglewood, California

Figure A-10b. Time History

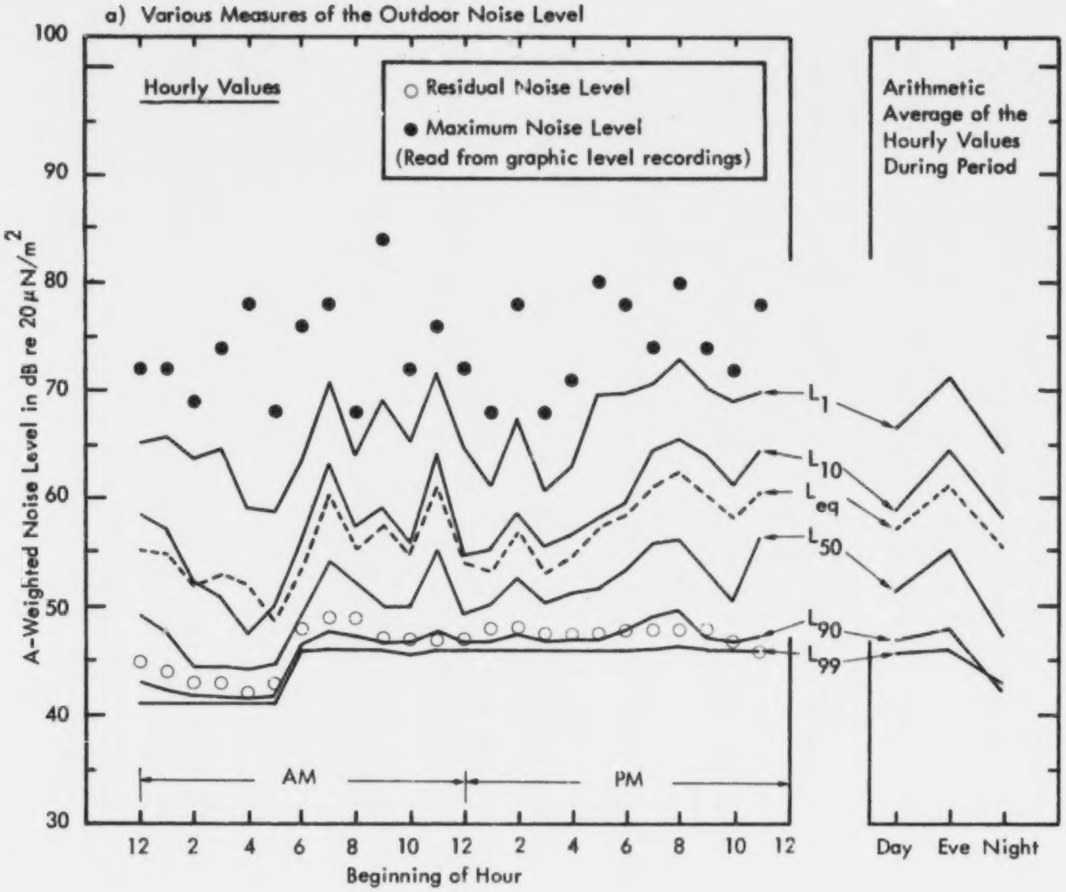
LOCATION J – 0000 Hours to 1200 Hours



LOCATION J – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise Was in Each 5 dB Interval for Three Time Periods

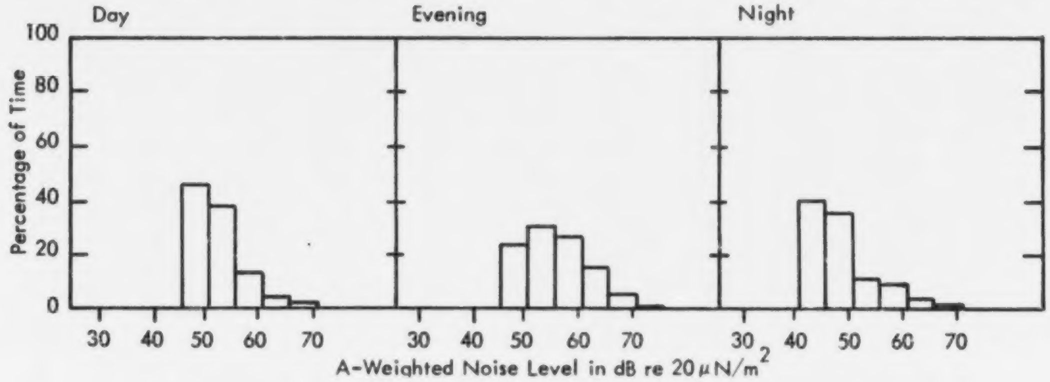
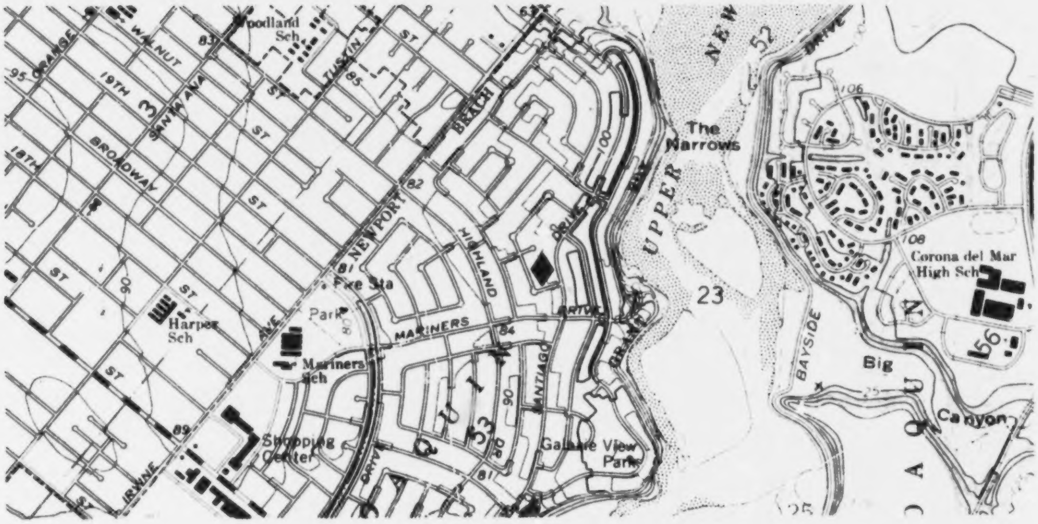


Figure A-10c. Summary of the 24-Hour Outdoor Noise Levels at Location J – Urban Residential


Woodland Sch
ORANGE
WALNUT
19TH
SANTA ANA
BROADWAY
18TH
TUSTIN
NEWPORT
BEACH
HIGHLAND
Fire Sta
Park
MARINERS
Harper Sch
Mariners Sch
Shopping Center
IRVINE
Galaxie View Park
DOVER
The Narrows
UPPER
NEW
23
52
BAYSIDE
Corona del Mar High Sch
Big Canyon
SAN JOAQUIN

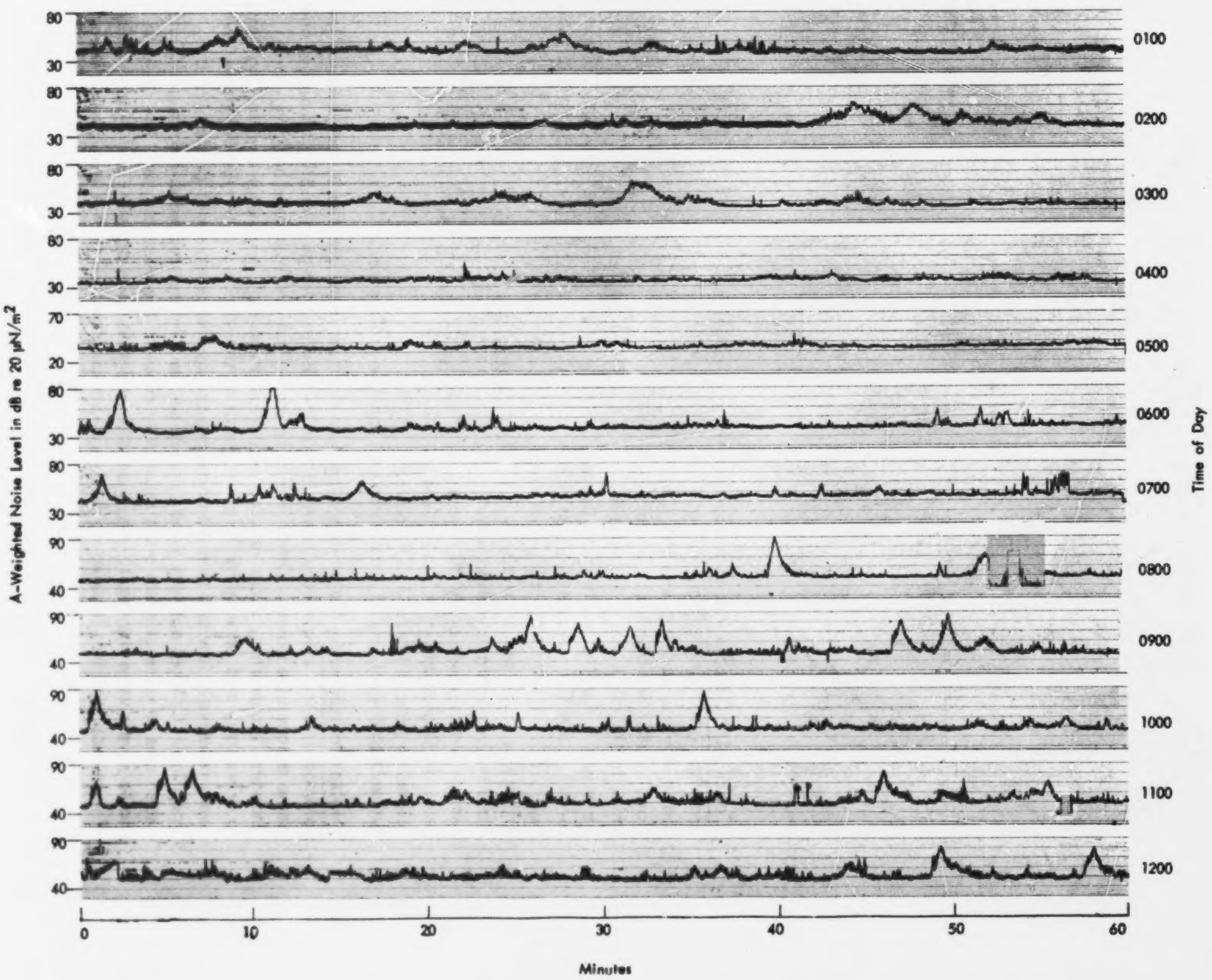
Community Description: Suburban residential; large single family dwellings only; 36-foot wide street serving only local traffic for a 2-block length; 0.4 mile to Dover Drive, a four-lane arterial; 1.4 miles to Newport Boulevard, 1.3 miles to Pacific Coast Highway, 1.8 miles to McArthur Boulevard, all major four-lane arterials; 3.5 miles to a major general aviation airport which has approximately 30 commercial jet flights daily; 0.3 mile from climbout ground track; 3.5 miles from takeoff brake release; 3.6 miles to the San Diego Freeway.

Noise Environment: Major intruding noise sources were created by commercial jet aircraft in their climbout pattern, a few helicopter events, propeller airplanes and some automobile noise. Other intruding events results from dogs barking, lawn mowers, hammering, a car revving up across the street, a garbage can rolling down a driveway, and jet engine thrust reversals at the airport. The residual noise levels were relatively low and seemed uninfluenced by the presence of crickets at this location. Cricket activity is noticeable on the 24-hour record during the 0100 hour when one or more crickets were relatively close to the microphone. The residual noise levels were apparently dominated by neighborhood activity and distant traffic. The microphone was located 45 feet from the curb and 20 feet above ground level.

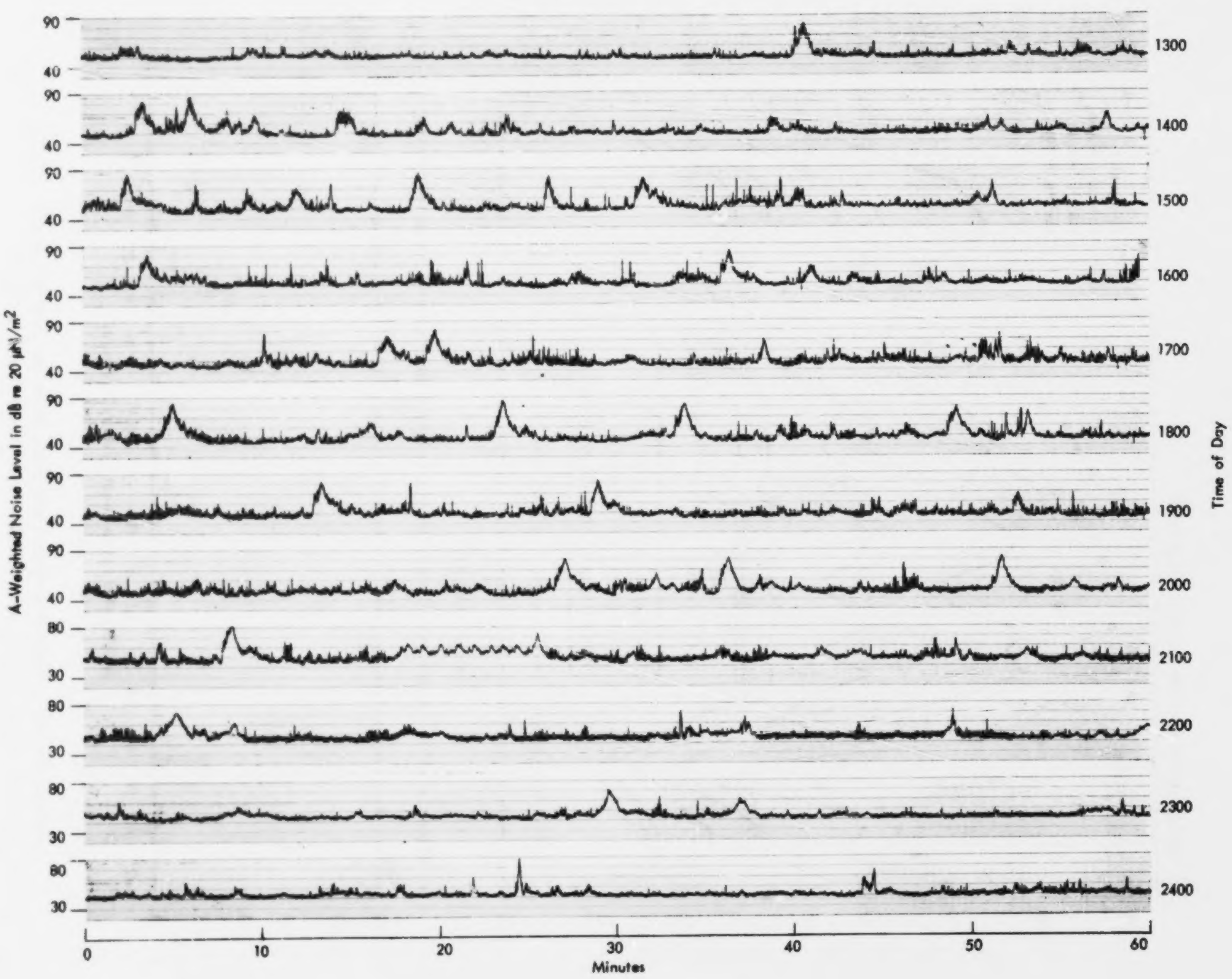
Figure A-11a. Location K – Urban Residential, Near Small Airport – Newport Beach, California

Figure A-11b. Time History

LOCATION K – 0000 Hours to 1200 Hours



LOCATION K – 1200 Hours to 2400 Hours



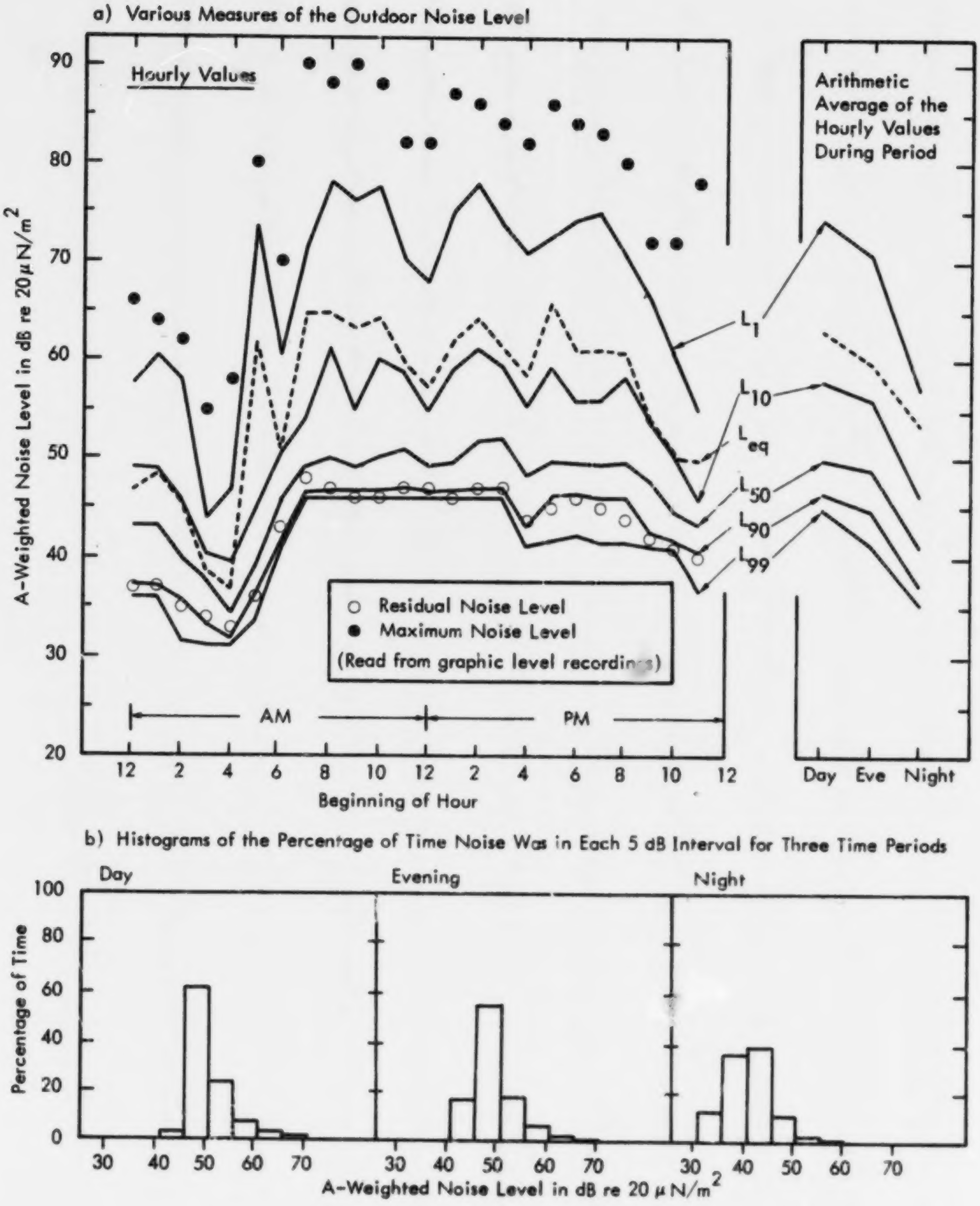
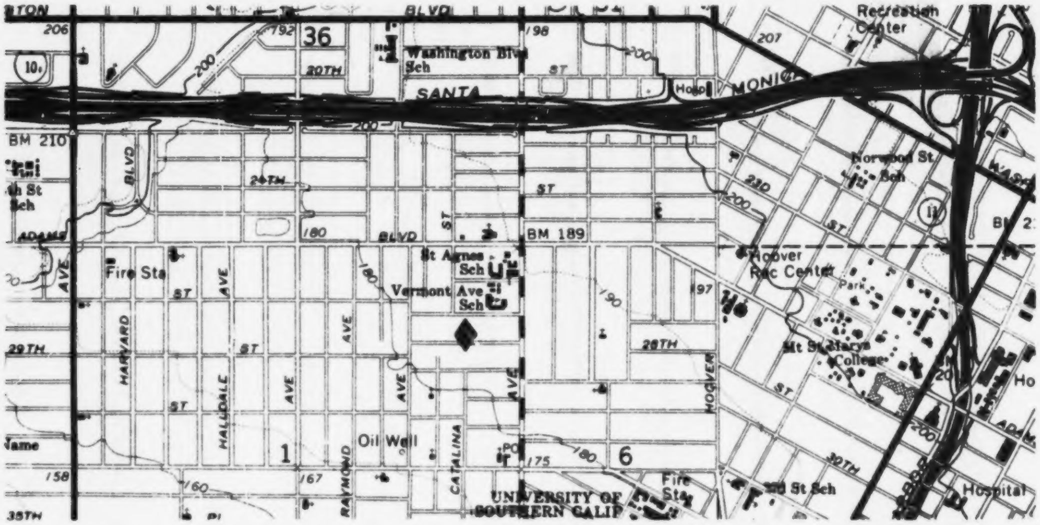


Figure A-11c. Summary of the 24-Hour Outdoor Noise Levels at Location K – Urban Residential, Near Small Airport



BLVD
36
20TH
Washington Blvd Sch
SANTA
MONICA
BM 210
24TH
BLVD
ADAMS
Fire Sta
St Agnes Sch
Vermont Ave Sch
BM 189
29TH
HARVARD
HALLDALE
28TH
HOOVER
Hoover Rec Center
Park
Mt St Marys College
Norwood St Sch
Recreation Center
Oil Well
CATALINA
RAYMOND
1
6
UNIVERSITY OF SOUTHERN CALIF
Fire Sta
30TH
Hospital
10
11

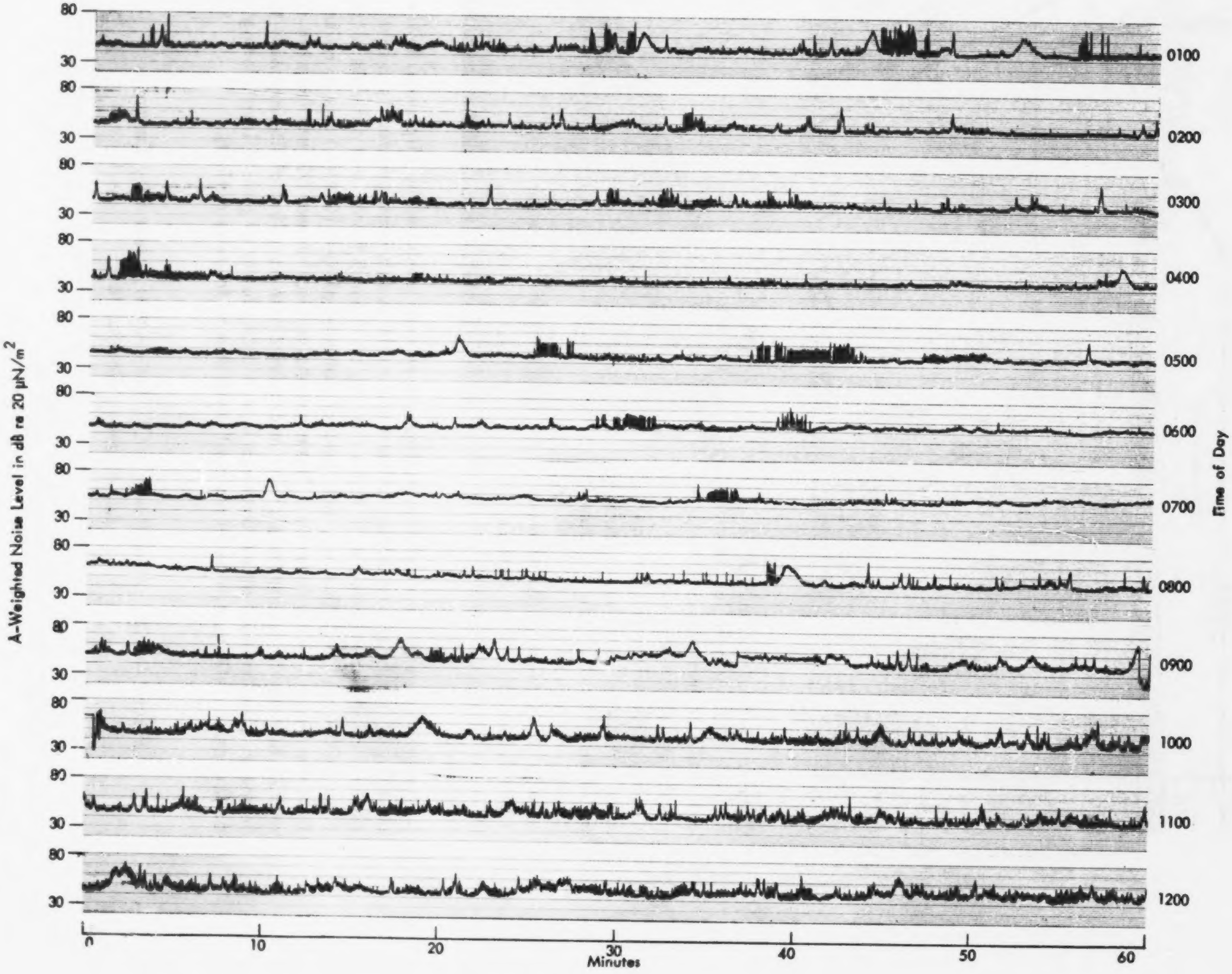
Community Description: Urban residential; mostly single family dwellings with light commercial district along nearby arterials; 36-foot wide street serving only residential traffic; 0.2 mile to Vermont Avenue, a four-lane major arterial; 0.2 mile to Adams Boulevard, a four-lane arterial; 0.5 mile to the Santa Monica Freeway; 1.1 miles to the Harbor Freeway; 2 miles to the major metropolitan downtown area.

Noise Environment: The major intruding events were produced by airplanes, helicopters, automobiles and dogs. Other measurable events were created by a lawn mower, an ice cream vendor, a radio playing on a porch front, and children playing. From 6:00 a.m. to 7:00 a.m., the residual noise level rose 10 dB(A) due to noise from the Santa Monica Freeway. The microphone location was 50 feet from the curb and 25 feet above ground level. The microphone was on a line of site exposure to the freeway. The residual noise level was 2 to 4 dB(A) lower at ground level during the 6:00 a.m. to 7:00 a.m. rise in residual level due to freeway activity.

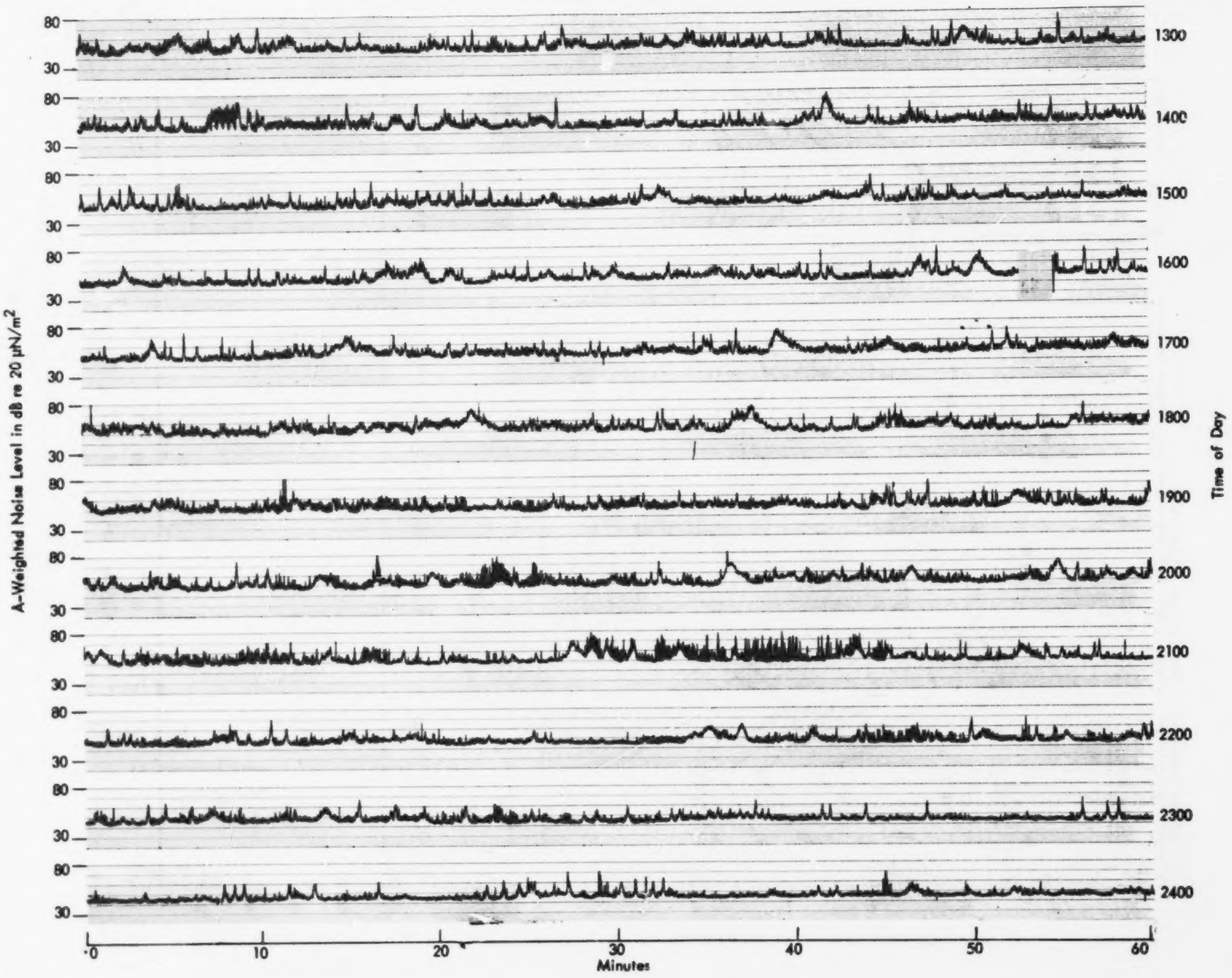
Figure A-12a. Location L – Old Residential, Near City Center – Los Angeles, California

Figure A-12b. Time History

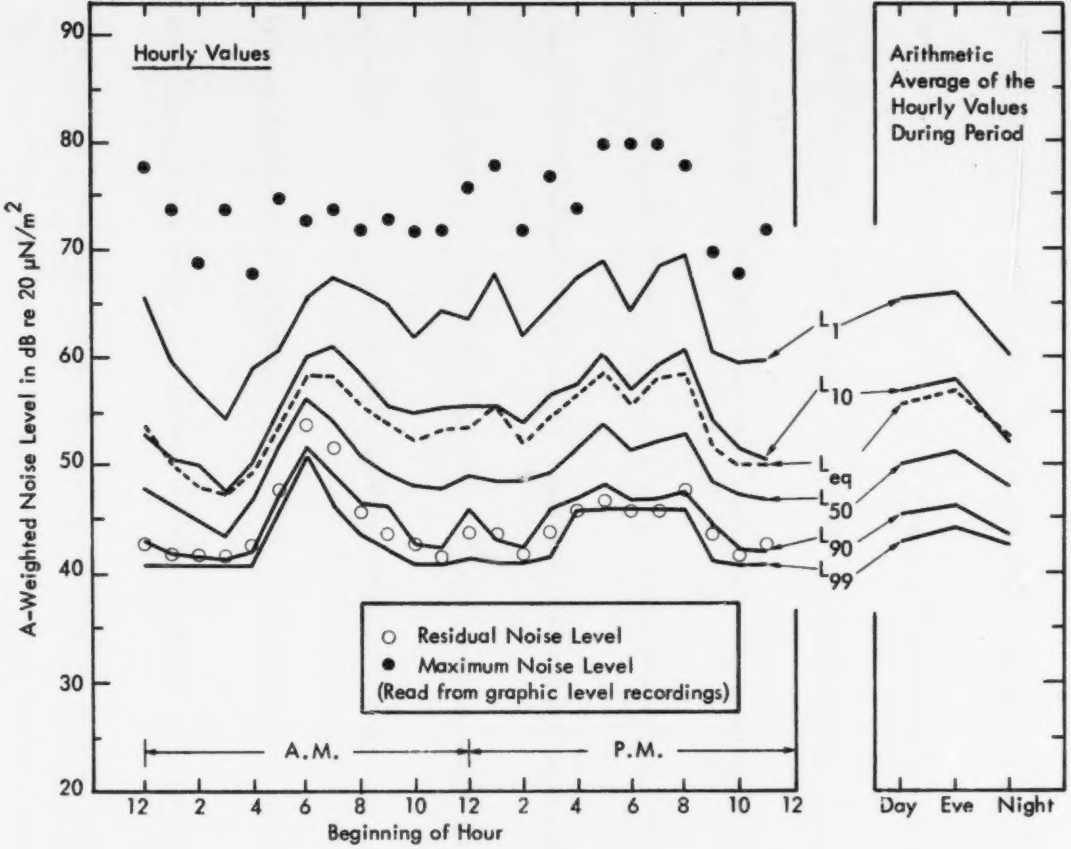
LOCATION L – 0000 Hours to 1200 Hours



LOCATION L – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise was in Each 5 dB Interval for Three Time Periods

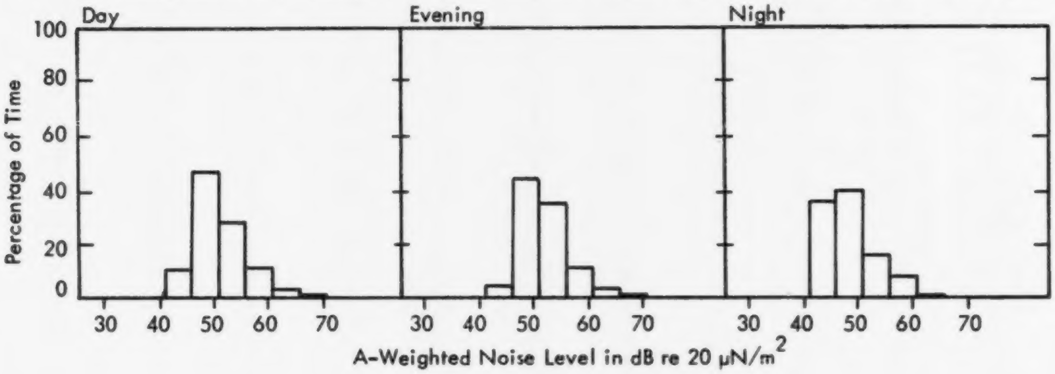
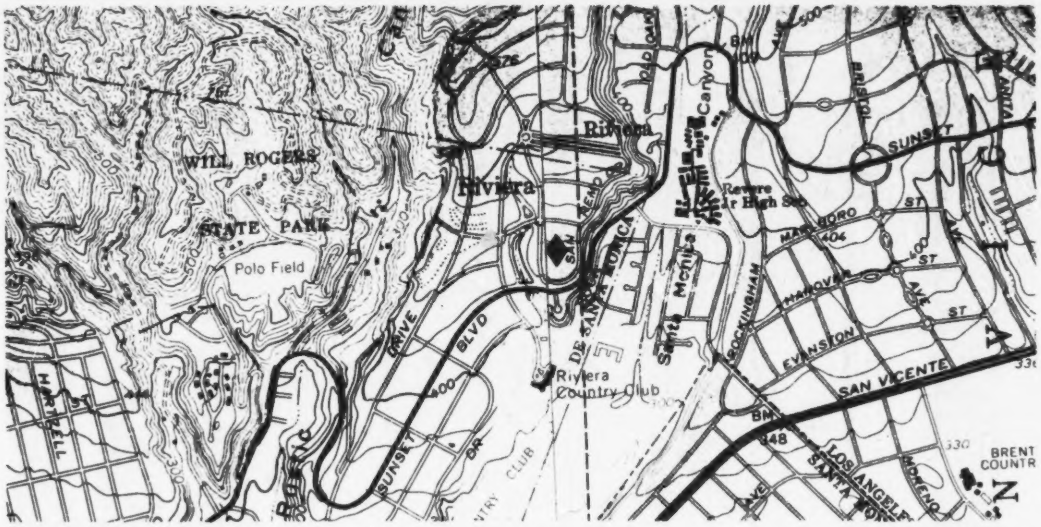


Figure A-12c. Summary of the 24-Hour Outdoor Noise Levels at Location L – Old Residential, Near City Center


WILL ROGERS
STATE PARK
Polo Field
Riviera
Riviera
Riviera
Country Club
SAN REMO
DE SANTA MONICA
Santa Monica
Canyon
BRISTOL
SUNSET
MARLBORO
HANOVER
EVANSTON
ROCKINGHAM
SAN VICENTE
SUNSET
BLVD
DRIVE
LOS ANGELES
BRENT
COUNTR
N

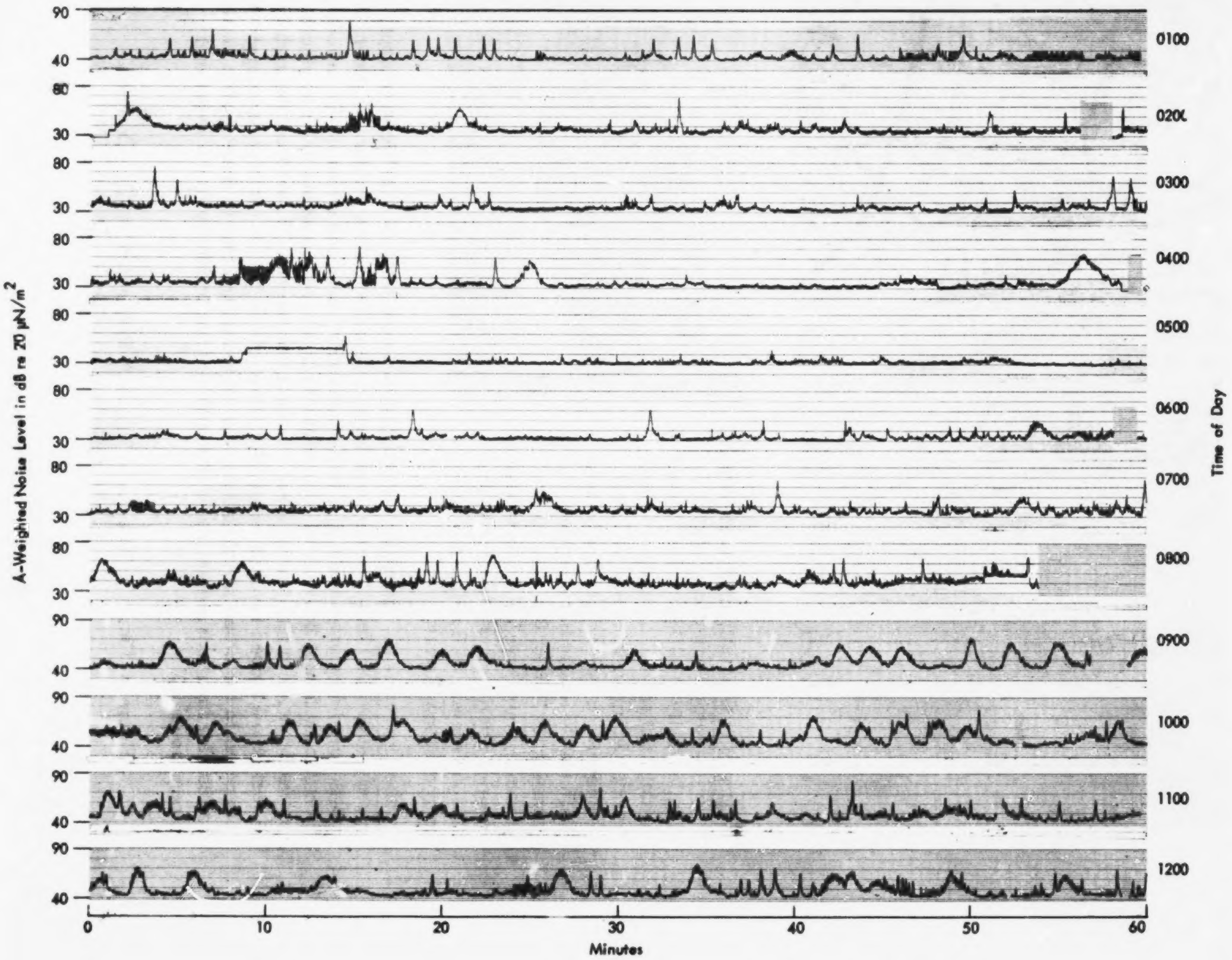
Community Description: Suburban residential; large moderately spaced single family dwellings only; 28-foot wide street serving a six square block residential area; 0.1 mile to Sunset Boulevard, a major four-lane arterial with mostly residential and little commercial traffic; 0.6 mile to San Vicente Voulevard, a four-lane residential arterial; 2.3 miles to the San Diego Freeway; 3.8 miles to a general aviation airport.

Noise Environment: The major intruding noises were from jet overflights at approximately 4000-6000 feet altitude, and from automobiles on the residential street. The other intruding sources were dogs in the residential area and street traffic intruding from nearby Sunset Boulevard. The residual noise level appeared to be dominated by traffic noise in the general area. The microphone was 25 feet from the curb and 4 feet above ground level so residential street traffic at this location is exaggerated compared to the other intruding events at this location, and to street traffic at other residential locations due to the microphone's closer proximity to the street and ground level.

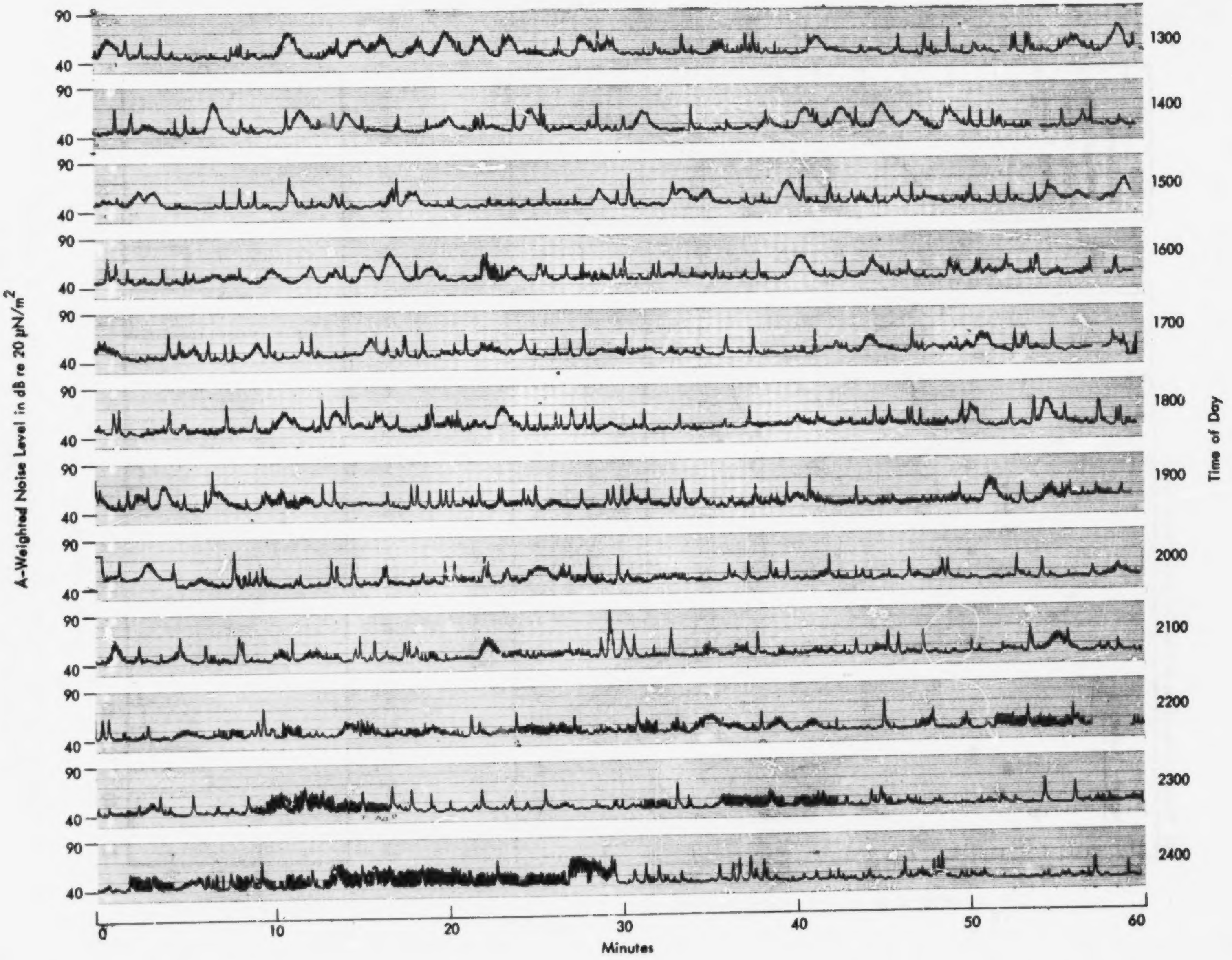
Figure A-13a. Location M – Suburban Residential at City Outskirts – Pacific Palisades, California

Figure A-13b. Time History

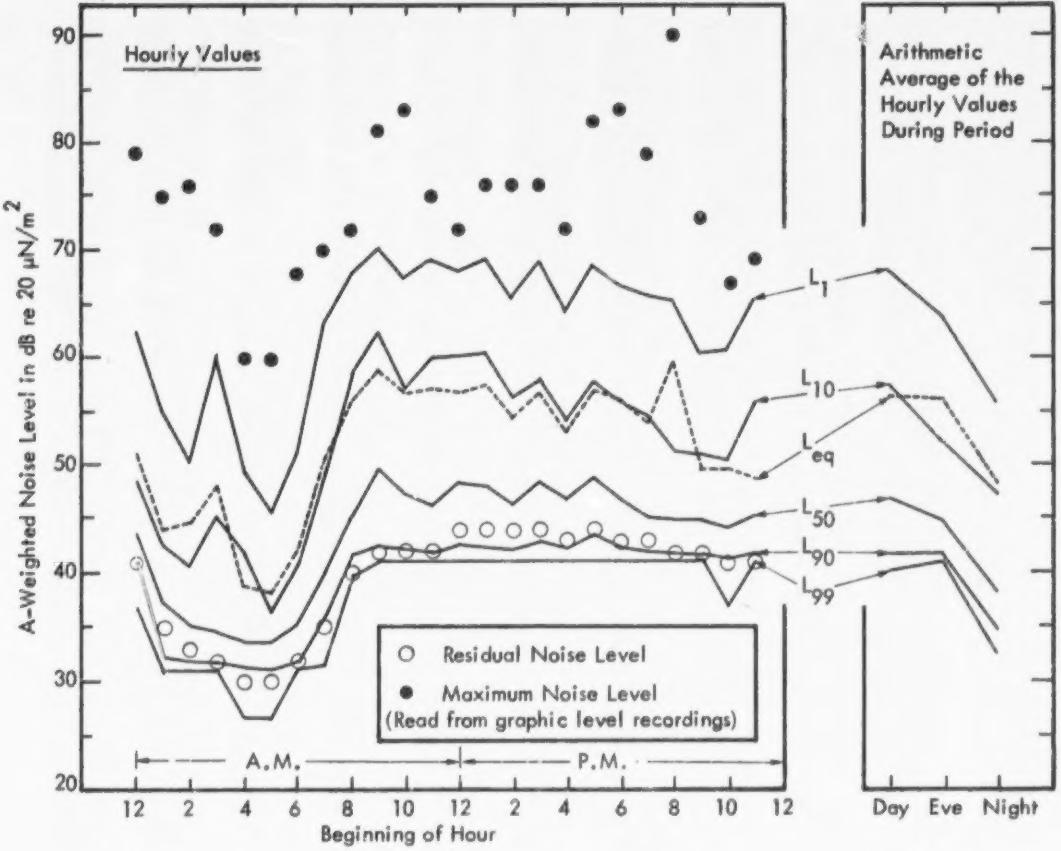
LOCATION M – 0000 Hours to 1200 Hours



LOCATION M – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise was in Each 5 dB Interval for Three Time Periods

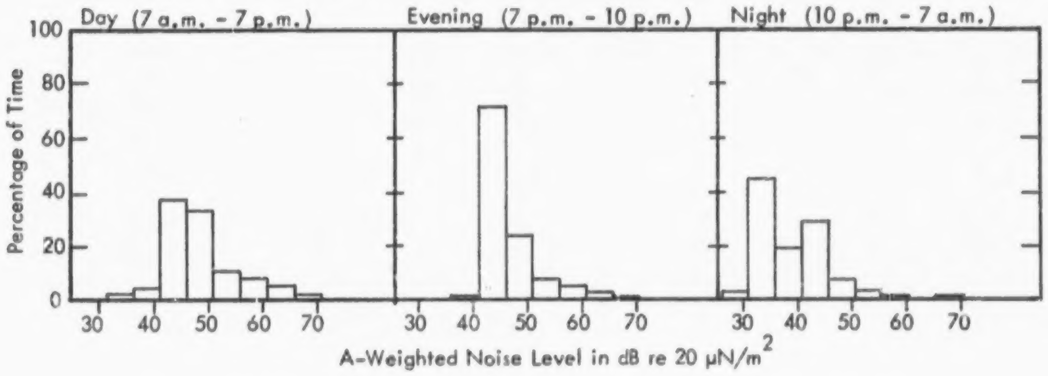
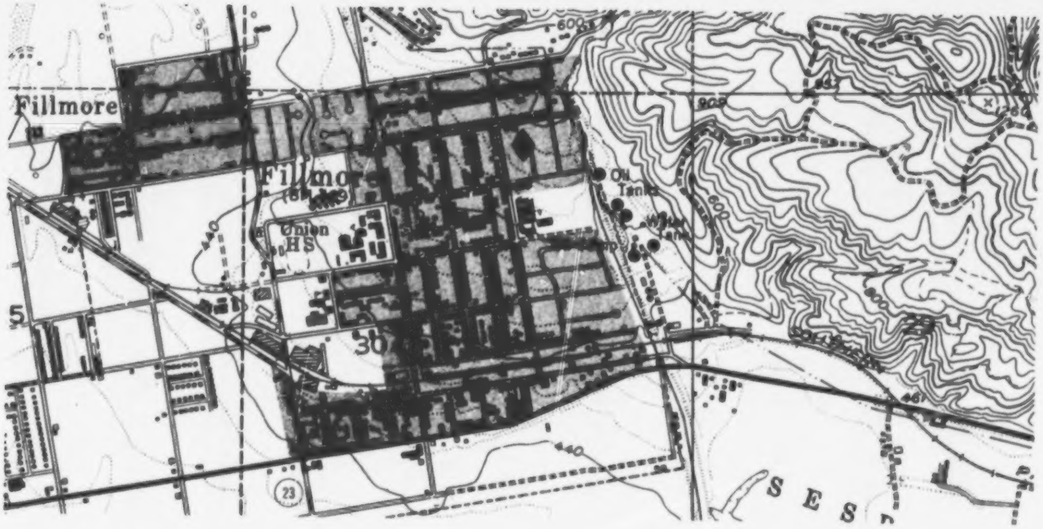


Figure A-13c. Summary of the 24-Hour Outdoor Noise Levels at Location M – Suburban Residential at City Outskirts

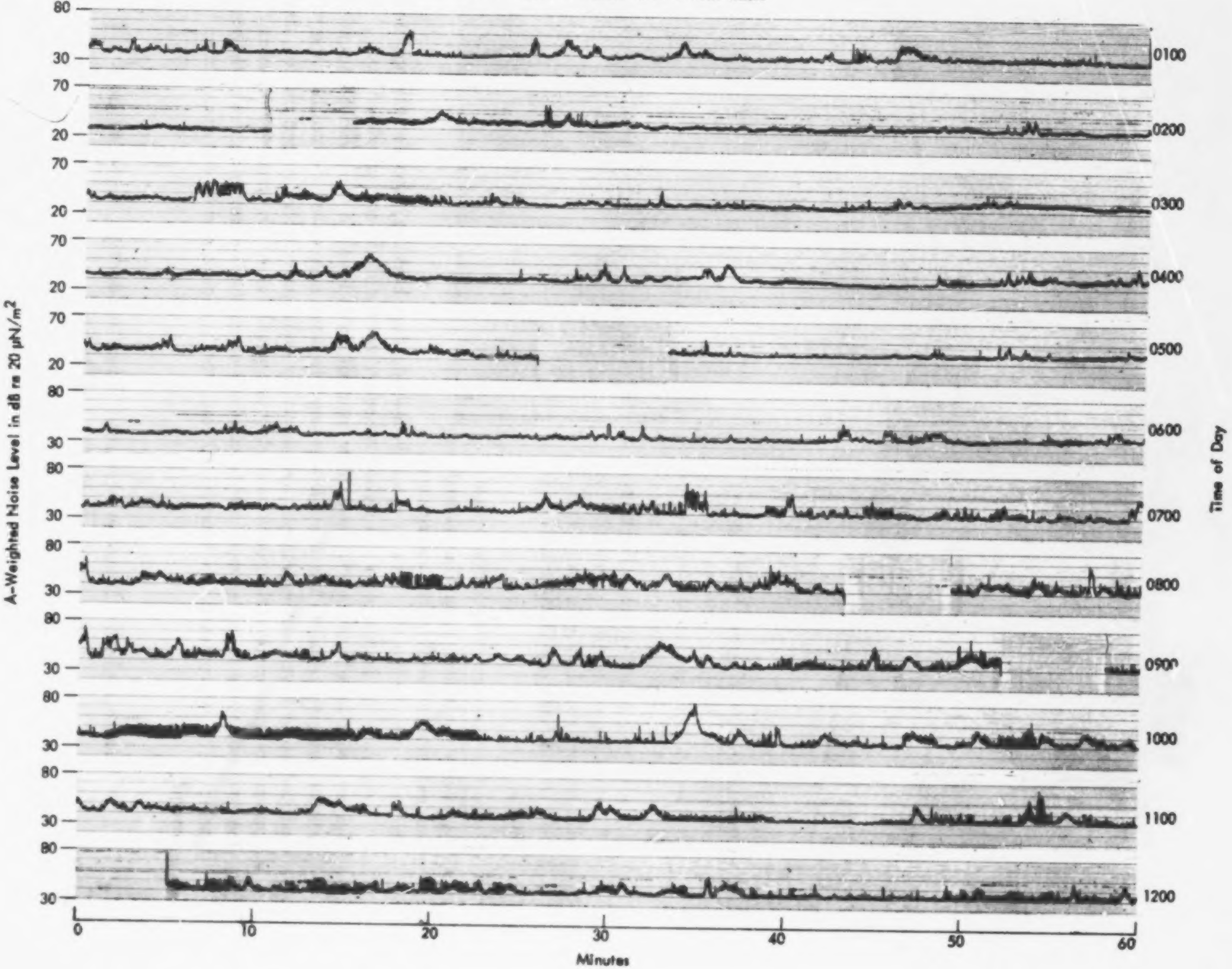


Community Description: Small town (population 6200); cul-de-sac with no through traffic; 2 to 4 blocks to the main north-south and east-west streets; 0.6 mile to State Highways 126 and 23 (two-lane surfaced highways); 0.4 mile to the main business district; 0.5 mile to the Southern Pacific Railroad track.

Noise Environment: The major intruding noises were from propeller aircraft and helicopter overflights, background traffic on nearby streets, cars in the cul-de-sac, dogs barking, people talking, and children playing in the area. A street sweeper in the cul-de-sac provided the highest noise level during the day. The residual noise level in the evening has some cricket activity present, but they do not seem to have controlled the noise. The residual noise level was apparently governed by community activity and traffic, and appears to have random fluctuations during any given hour. In large urban areas, the residual noise level appears either constant or gradually changing over any hour period. The microphone was located 20 feet from the curb and 4 feet above the ground.

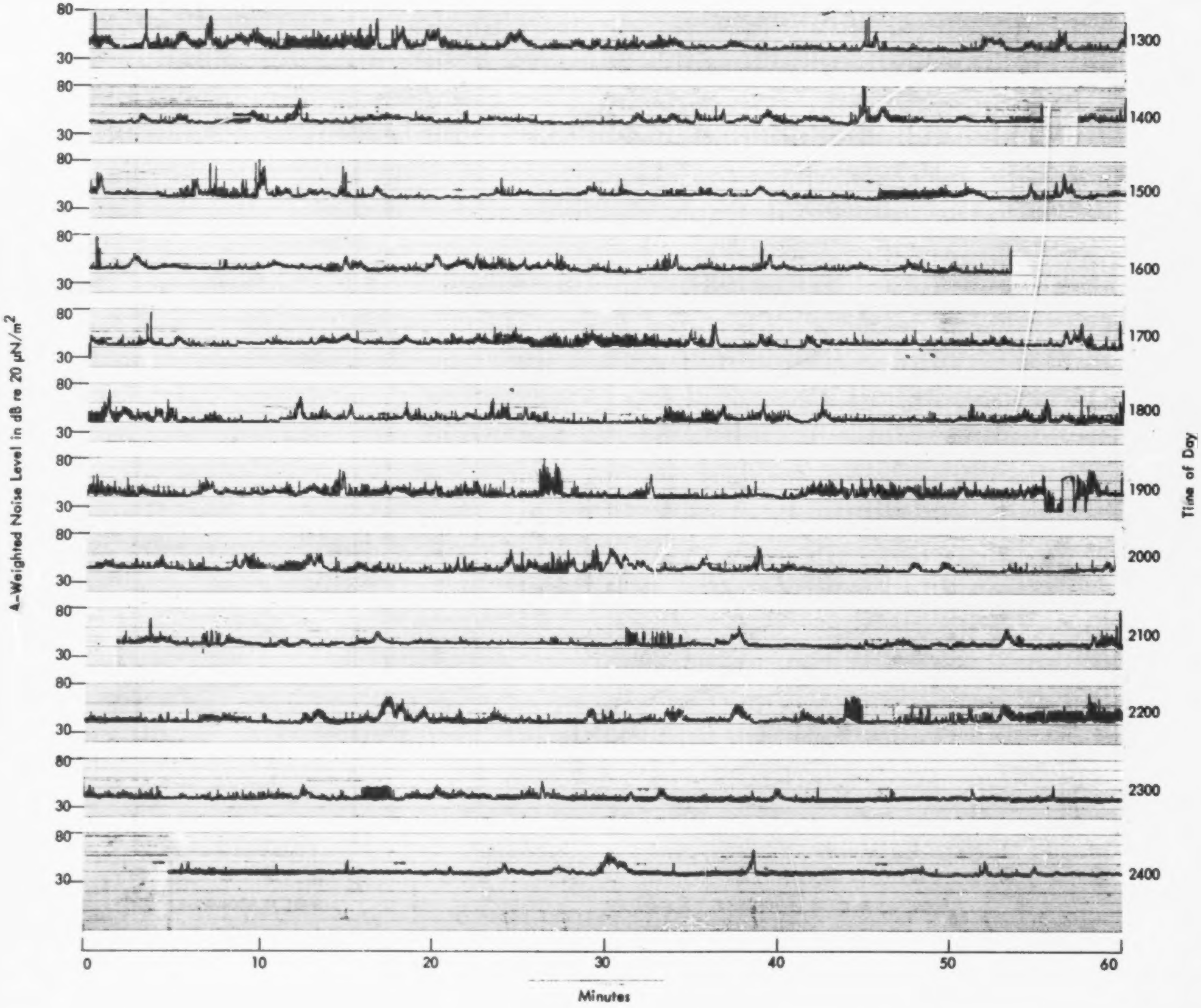
Figure A-14a. Location N — Small Town Residential, Cul-de-Sac — Fillmore, California

Figure A-14b. Time History

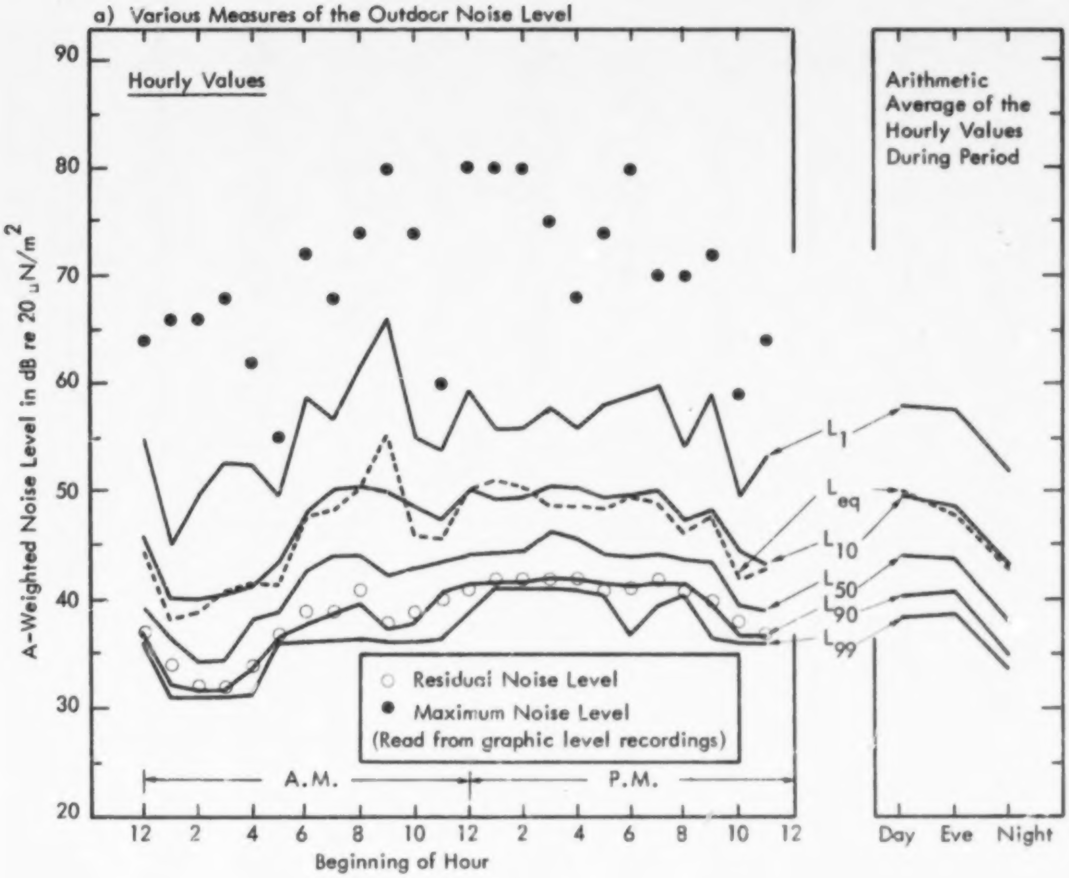


LOCATION N – 0000 Hours to 1200 Hours

LOCATION N – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise was in Each 5 dB Interval for Three Time Periods

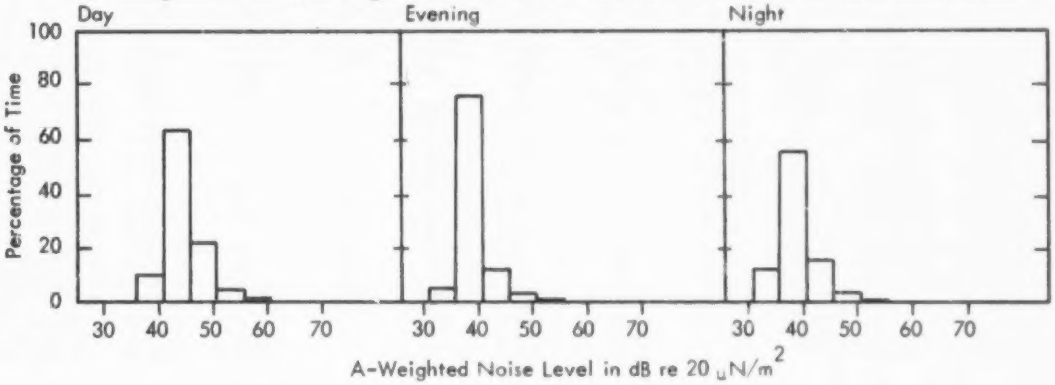
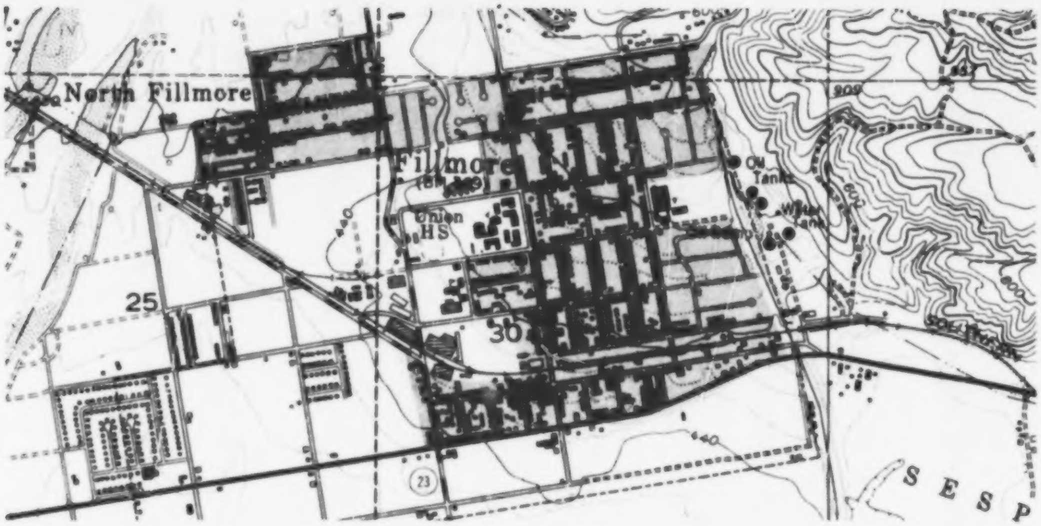


Figure A-14c. Summary of the 24-Hour Outdoor Noise Levels at Location N – Small Town Residential, Cul-de-Sac



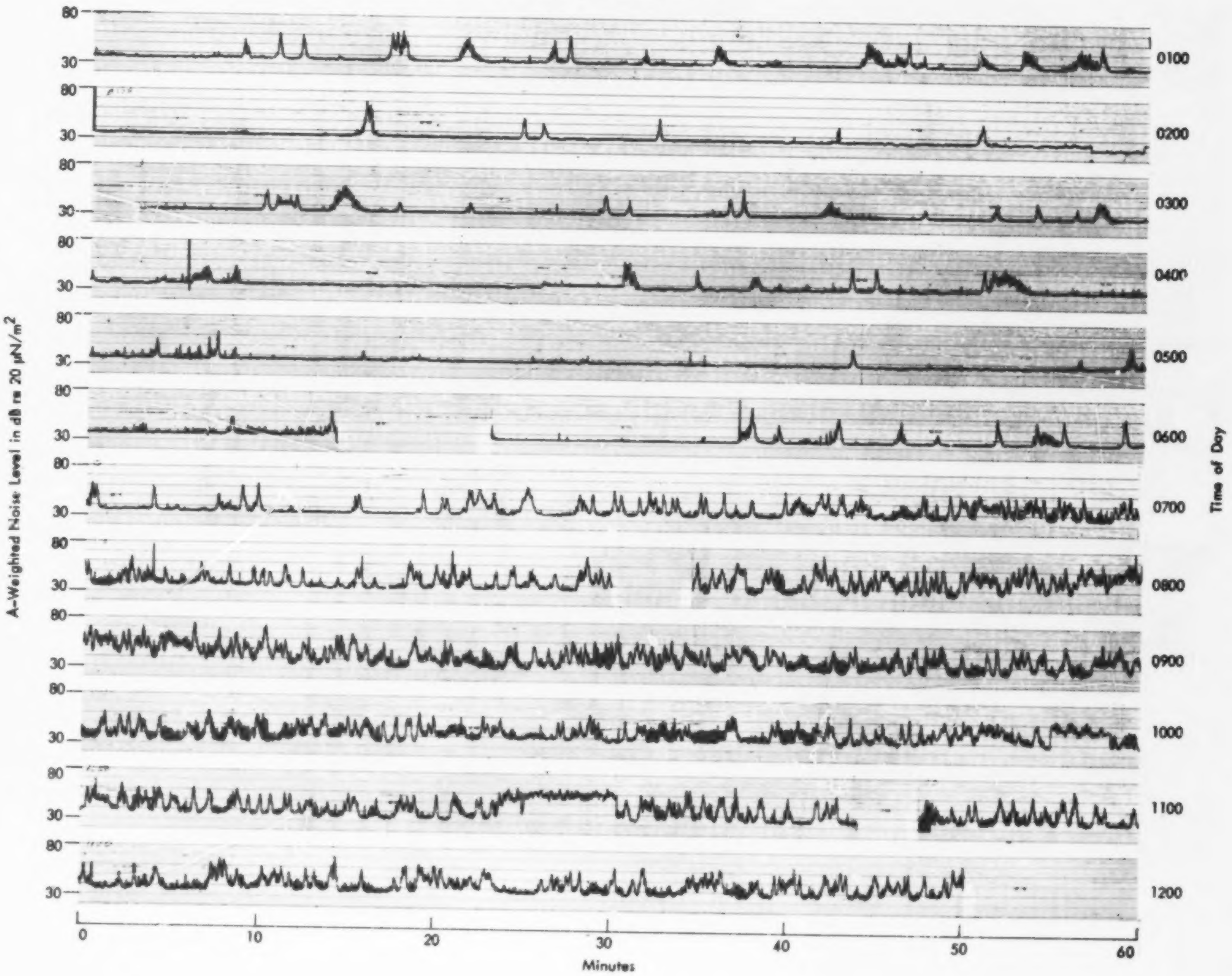
Community Description: Small town (population 6200); main street residential area; 0.3 mile to State Highway 23 and 0.6 mile to State Highway 126, both two-lane surfaced highways; 0.2 mile to the main business district; 0.5 mile to the Southern Pacific Railroad track.

Noise Environment: The major intruding noise sources were from main street traffic, airplanes, trucks and motorcycles, horns and lawn mowers. During the midnight to 0100 time period, there were as many aircraft overflights as cars passing on the main street. The residual noise level in the late evening hours appeared more steady than at the cul-de-sac location 5 blocks away (location N). The microphone was located 55 feet from the curb and 5 feet above ground.

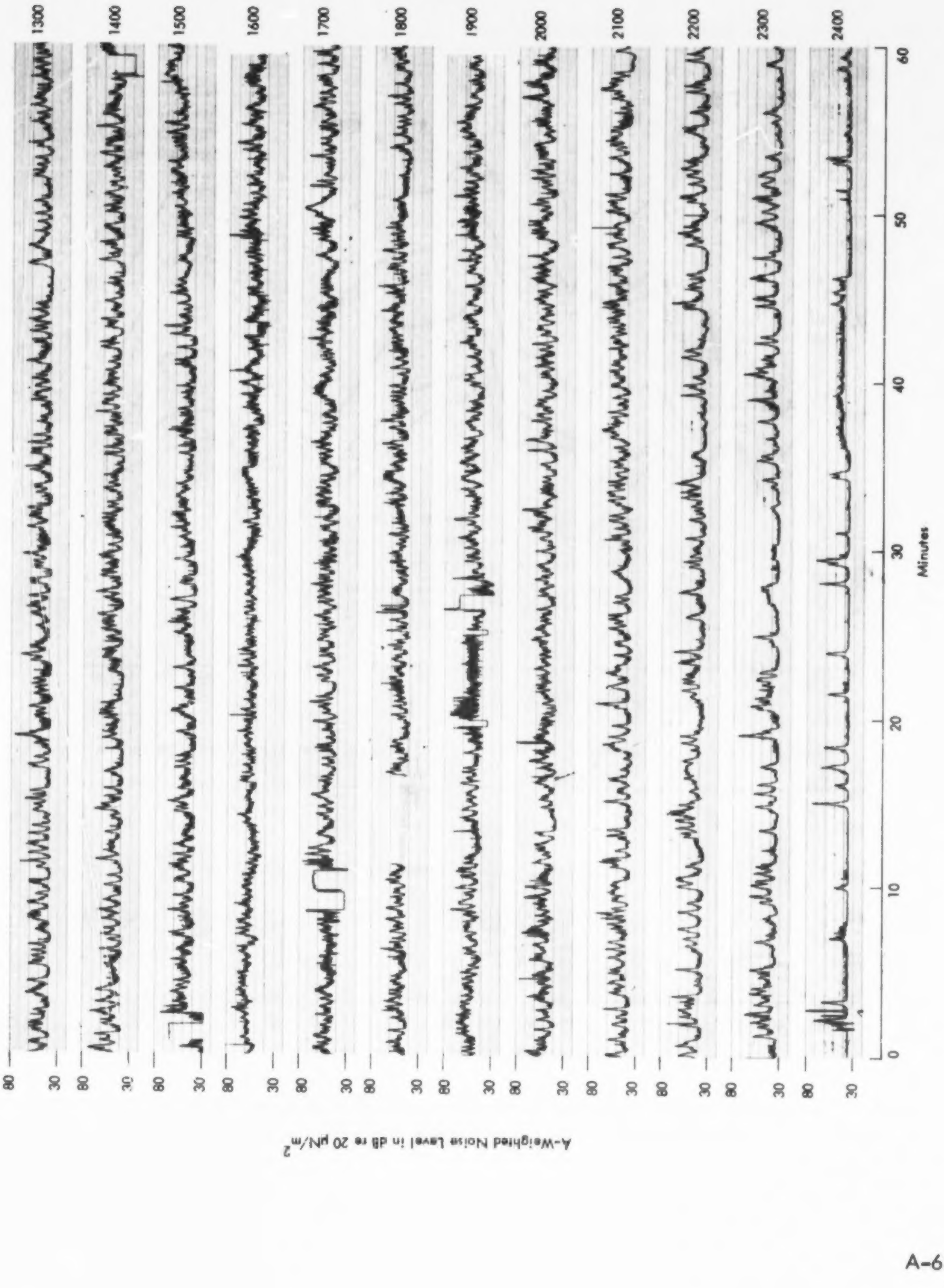
Figure A-15a. Location O – Small Town Residential, Main Street – Fillmore, California

Figure A-15b. Time History

LOCATION O – 0000 Hours to 1200 Hours



LOCATION O – 1200 Hours to 2400 Hours



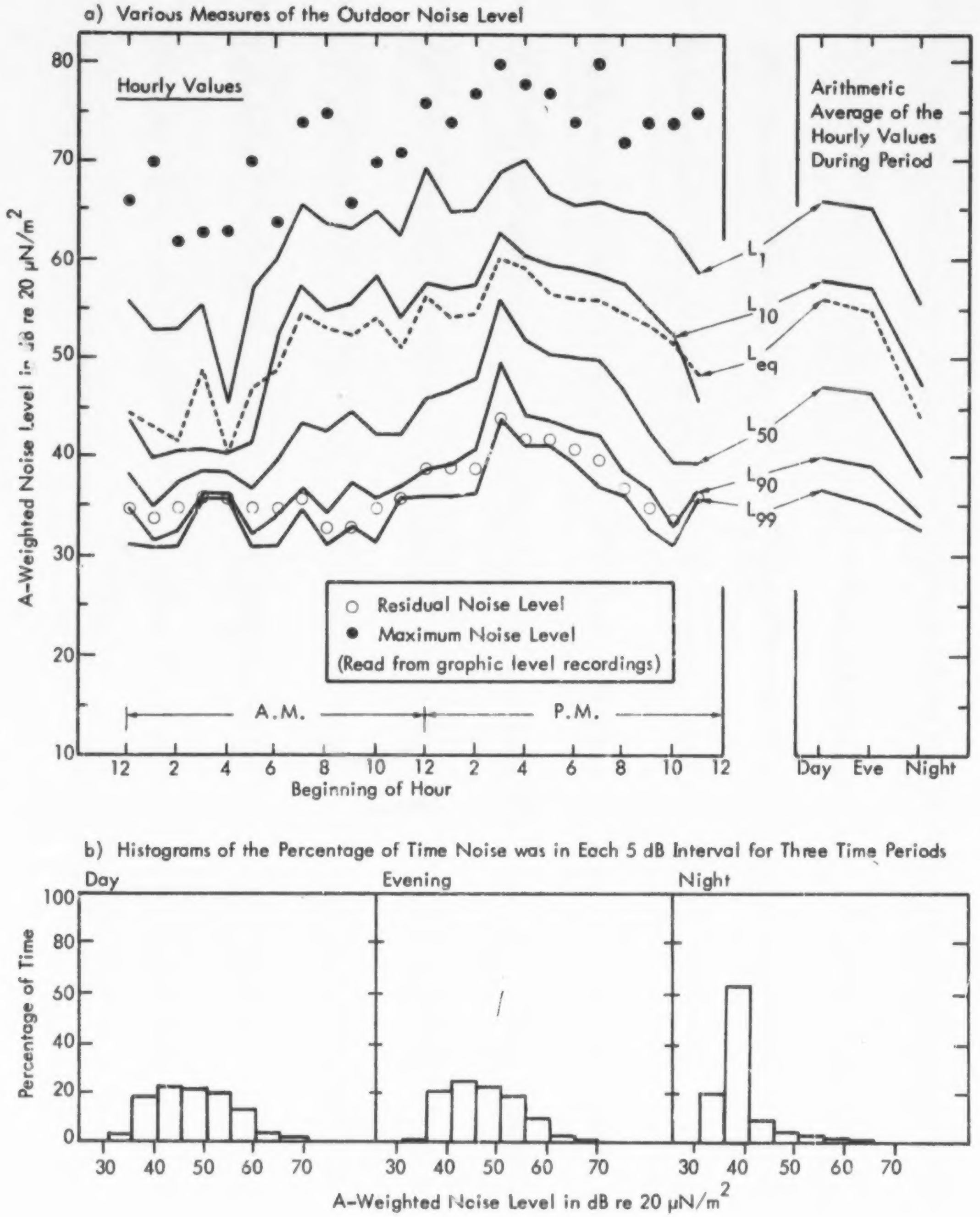
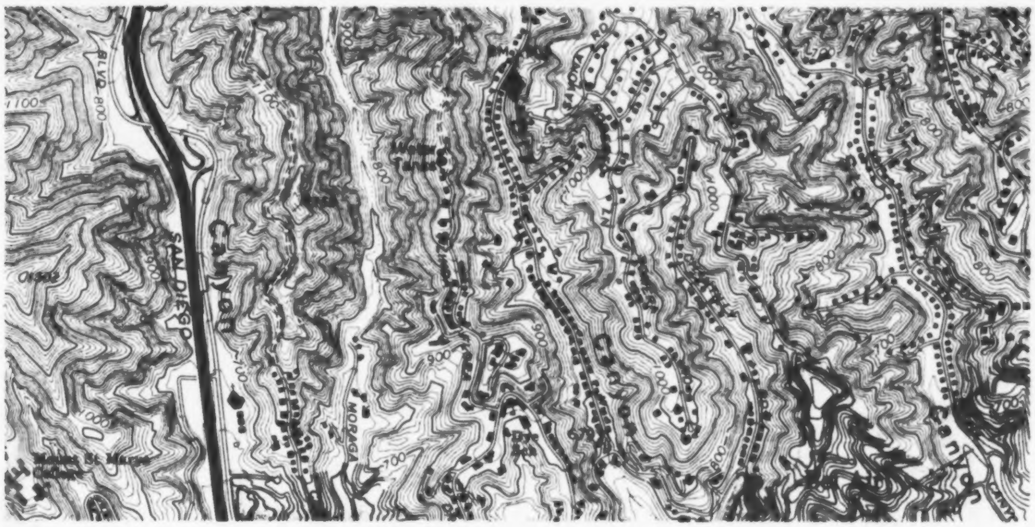


Figure A-15c. Summary of the 24-Hour Outdoor Noise Levels at Location O – Small Town Residential, Main Street



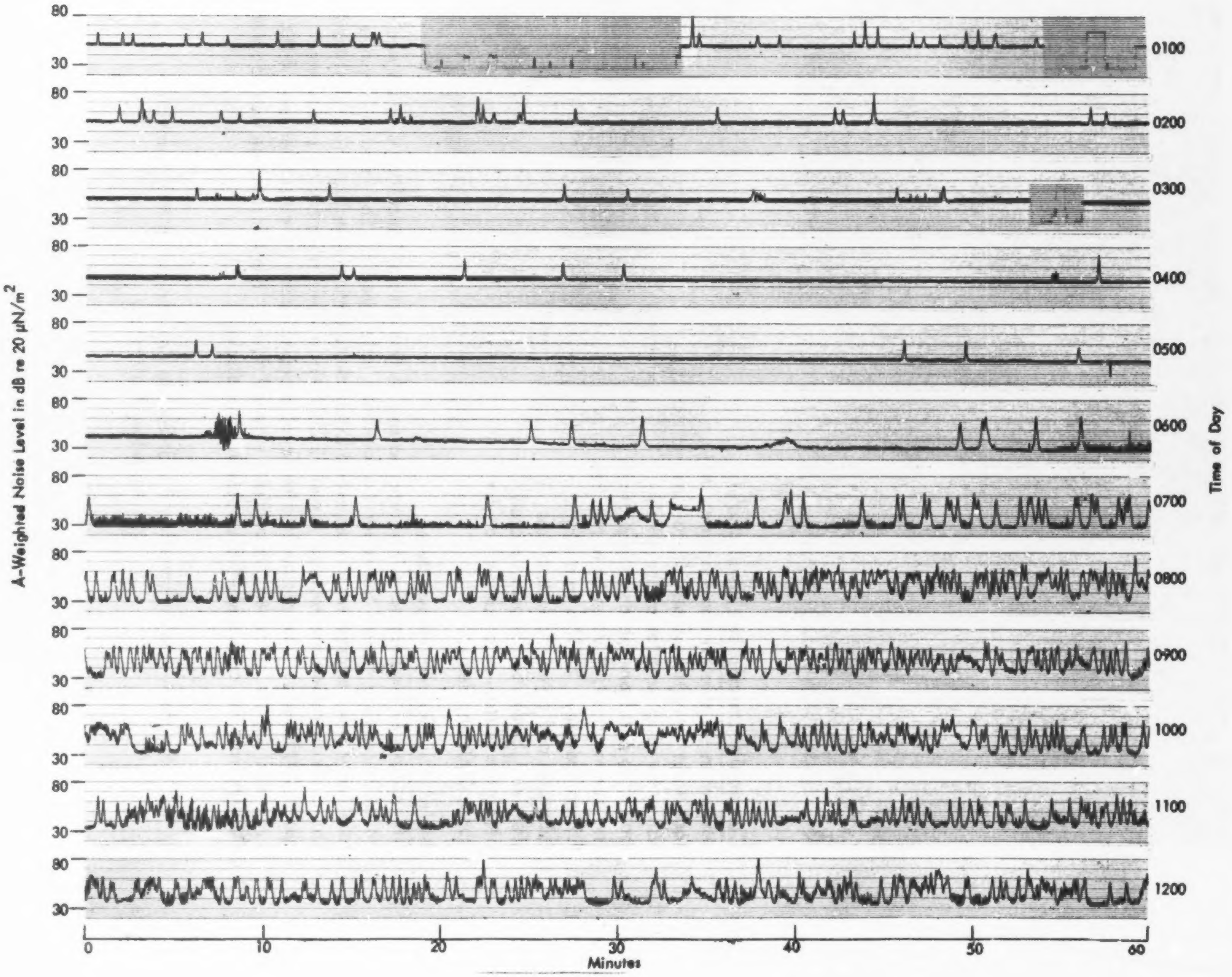
Community Description: High income surburban residential canyon area, 30-foot wide two-lane street, 2.5 miles long, forming an arterial for all the traffic to and from the dwellings along the canyon road, 0.75 mile to the San Diego Freeway, 2 miles to a major suburban and commercial business district. Street and houses located along the bottom of a narrow canyon about 300 feet deep.

Noise Environment: Heavy street traffic formed the dominant intruding noise. A few aircraft overflights, dogs and children playing formed the other noticeable single events. The residual level is relatively low, except when dominated by crickets during evening and night hours. The crickets raised the residual noise 12 dB(A) in a 20-minute period beginning about 2000 hours. The residual noise level dropped about 15 dB(A) between 4:00 a.m. and 6:00 a.m. when the crickets quieted down. The microphone was located 40 feet from the curb and 25 feet above ground level.

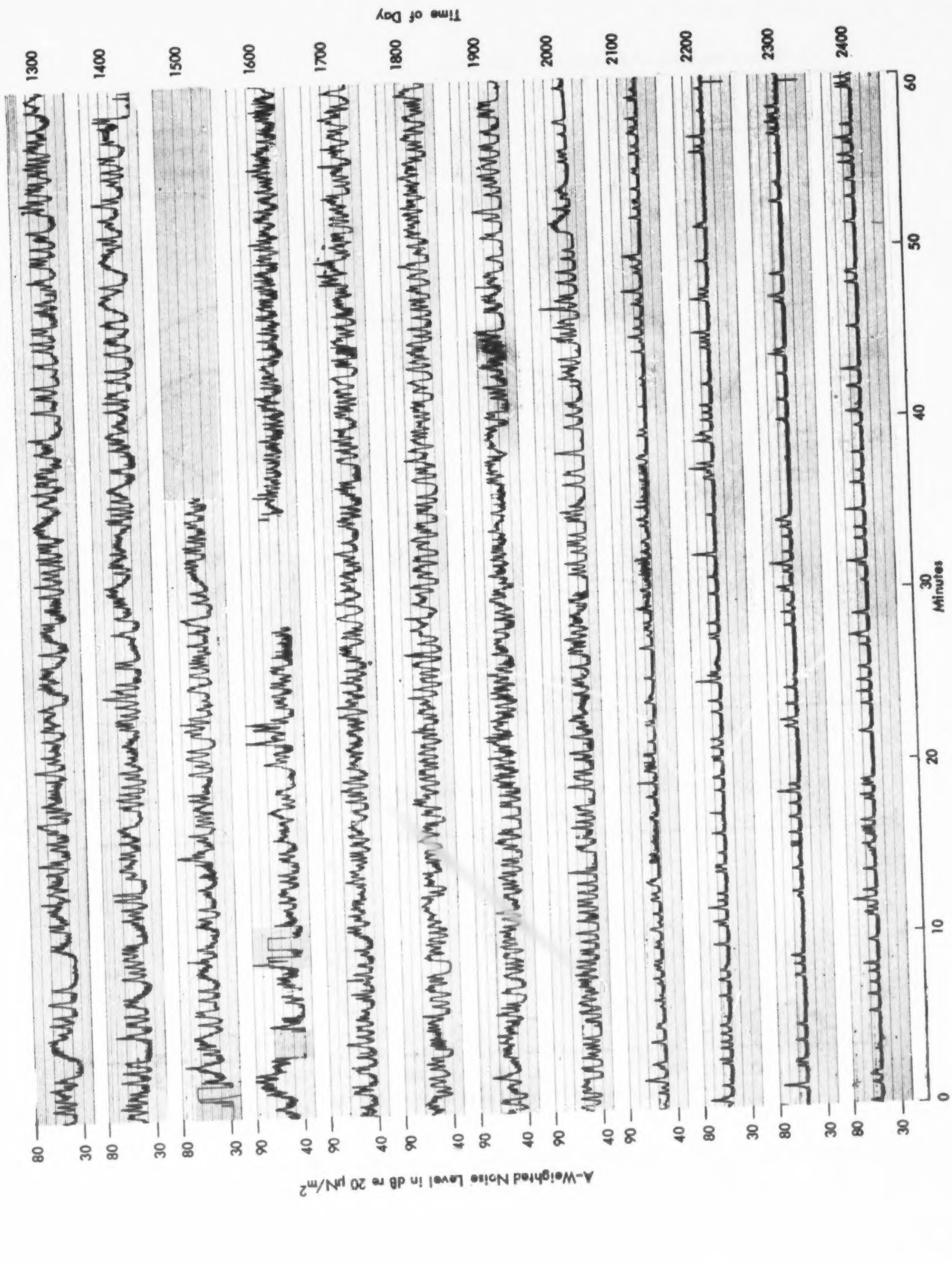
Figure A-16a. Location P – Suburban Residential in Hill Canyon – Los Angeles, California

Figure A-16b. Time History

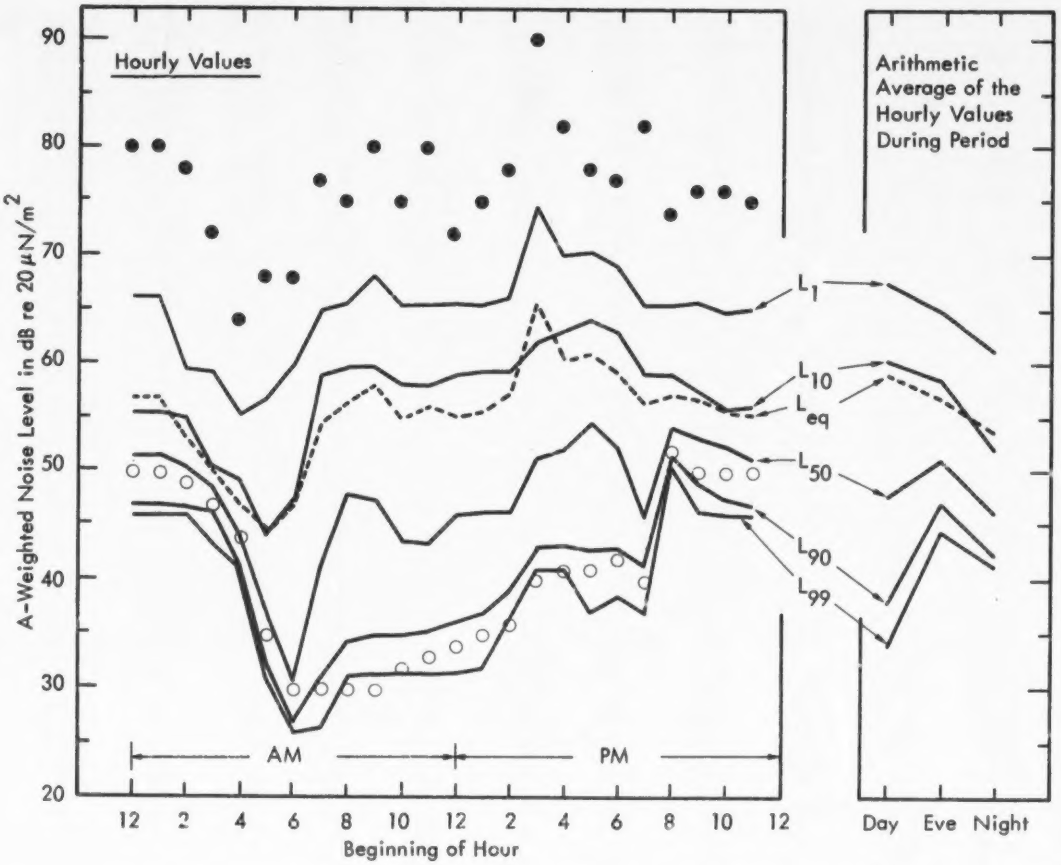
LOCATION P – 0000 Hours to 1200 Hours



LOCATION P – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise Was in Each 5 dB Interval for Three Time Periods

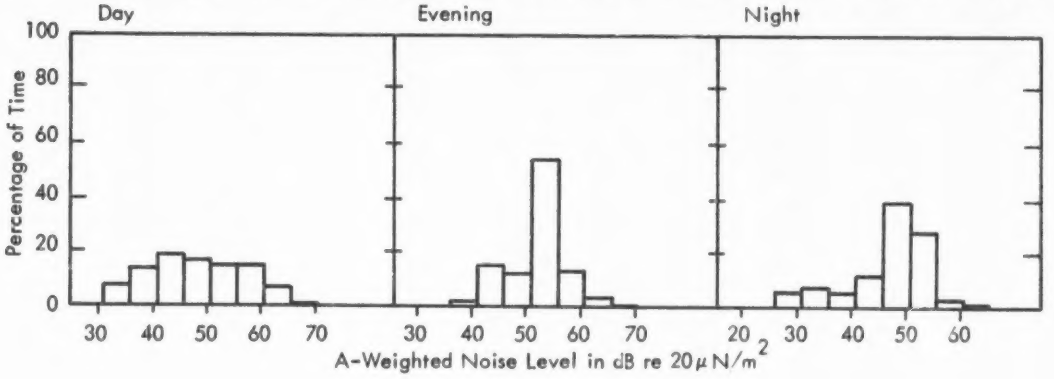
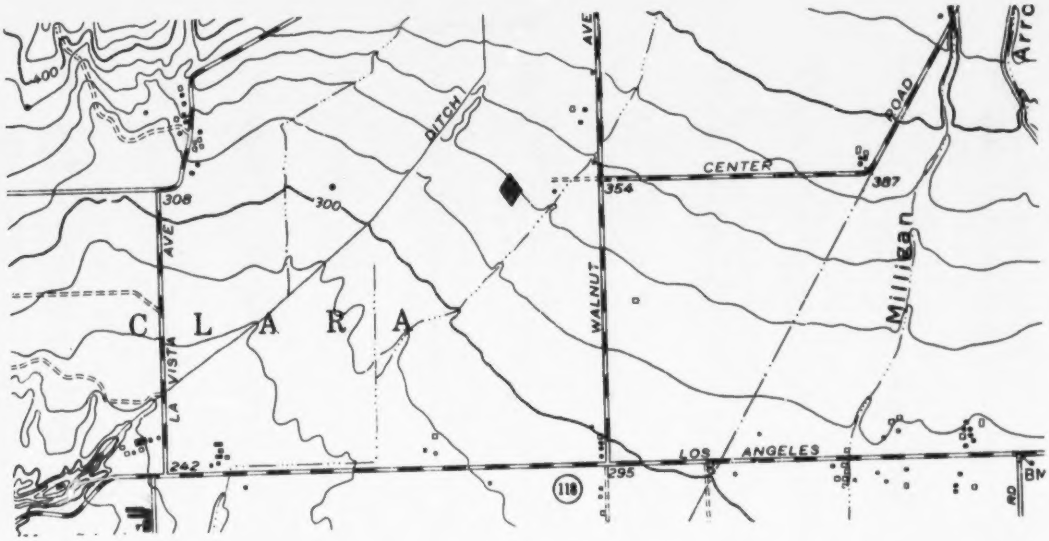


Figure A-16c. Summary of the 24-Hour Outdoor Noise Levels at Location P — Suburban Residential in Hill Canyon



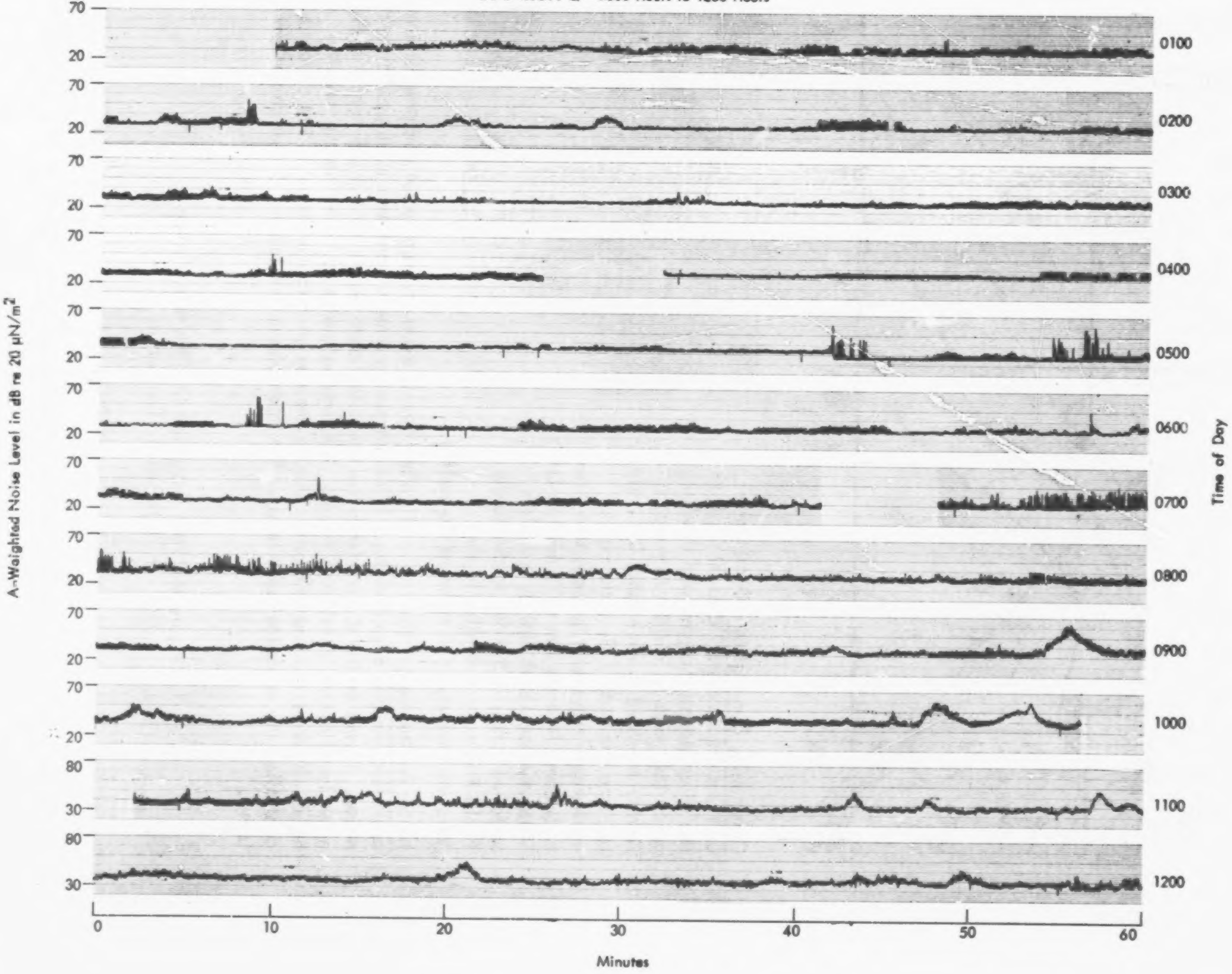
Community Description: Rural agricultural area tomato field; 50 yards to the trees around the yard and dwelling area; 160 yards to Walnut Avenue, a lightly traveled surface road; 0.6 mile to State Highway 118, a two-lane moderately traveled highway; 0.6 mile to LaLoma Avenue and 0.75 mile to La Vista Avenue, both lightly traveled surfaced roads; 3.5 miles to the Santa Paula Freeway; 3.6 miles to the Ventura Freeway; 4.5 miles to Camarillo.

Noise Environment: The major intruding events were created by jet and propeller aircraft flyovers and dogs barking. Other intruding events were from background traffic noise. Trucks on the distant freeways could be heard distinctly but did not raise the noise level above its residual value. The residual noise level during the evening hours was dominated by crickets. During the day an orchard pruner in the distance controlled the minimum noise level. The microphone was located 5 feet above ground level.

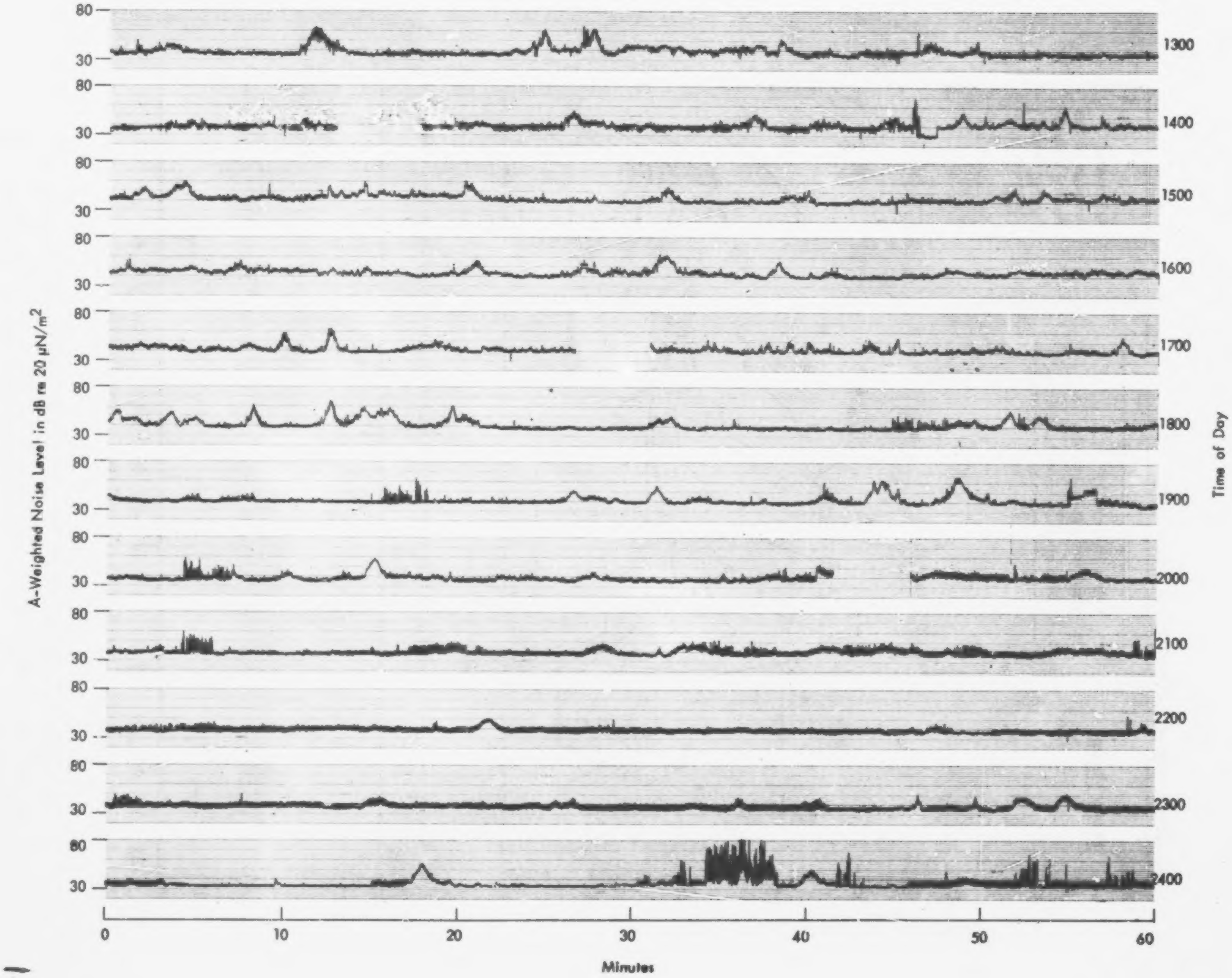
Figure A-17a. Location Q – Farm in Valley –
Camarillo, California

Figure A-17b. Time History

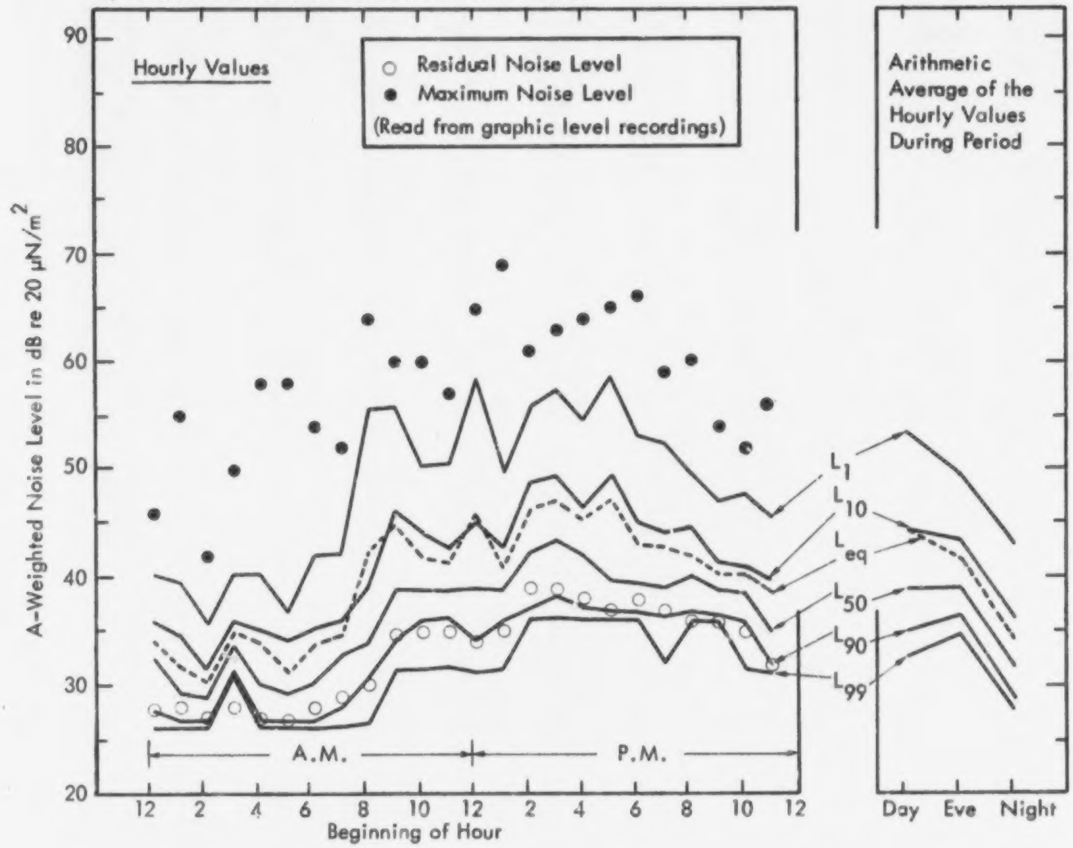
LOCATION Q – 0000 Hours to 1200 Hours



LOCATION Q – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise was in Each 5 dB Interval for Three Time Periods

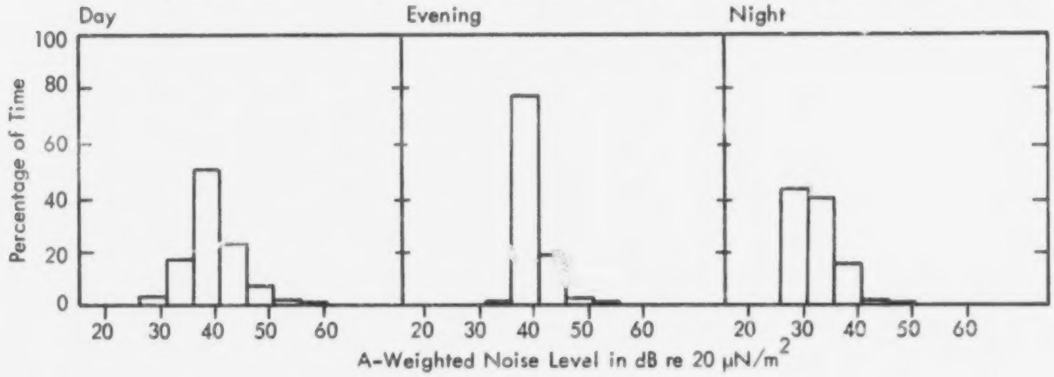
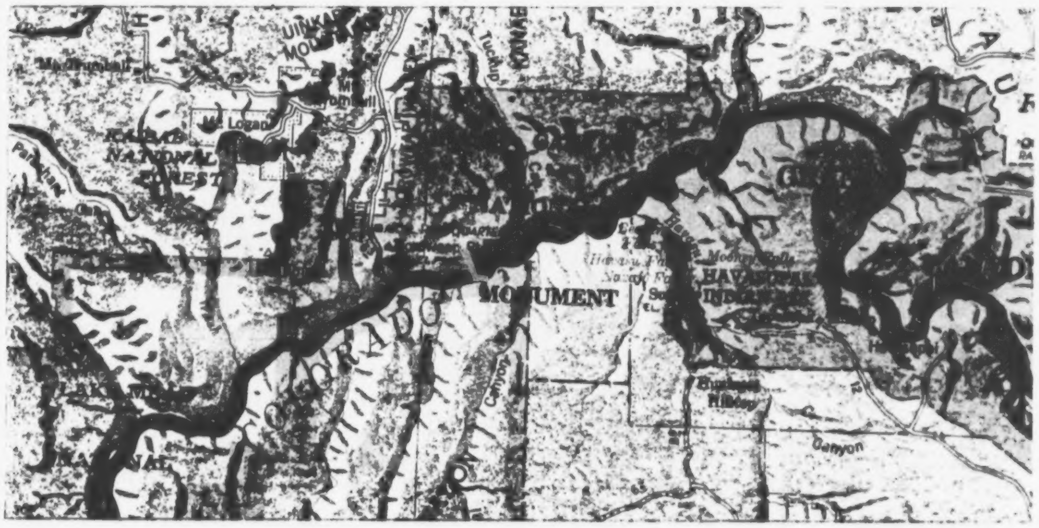


Figure A-17c. Summary of the 24-Hour Outdoor Noise Levels at Location Q – Farm in Valley



Community Description: Remote wilderness; north rim of the Grand Canyon; a campground with four picnic tables accessible by a 100-mile dirt road from St. George, Utah.

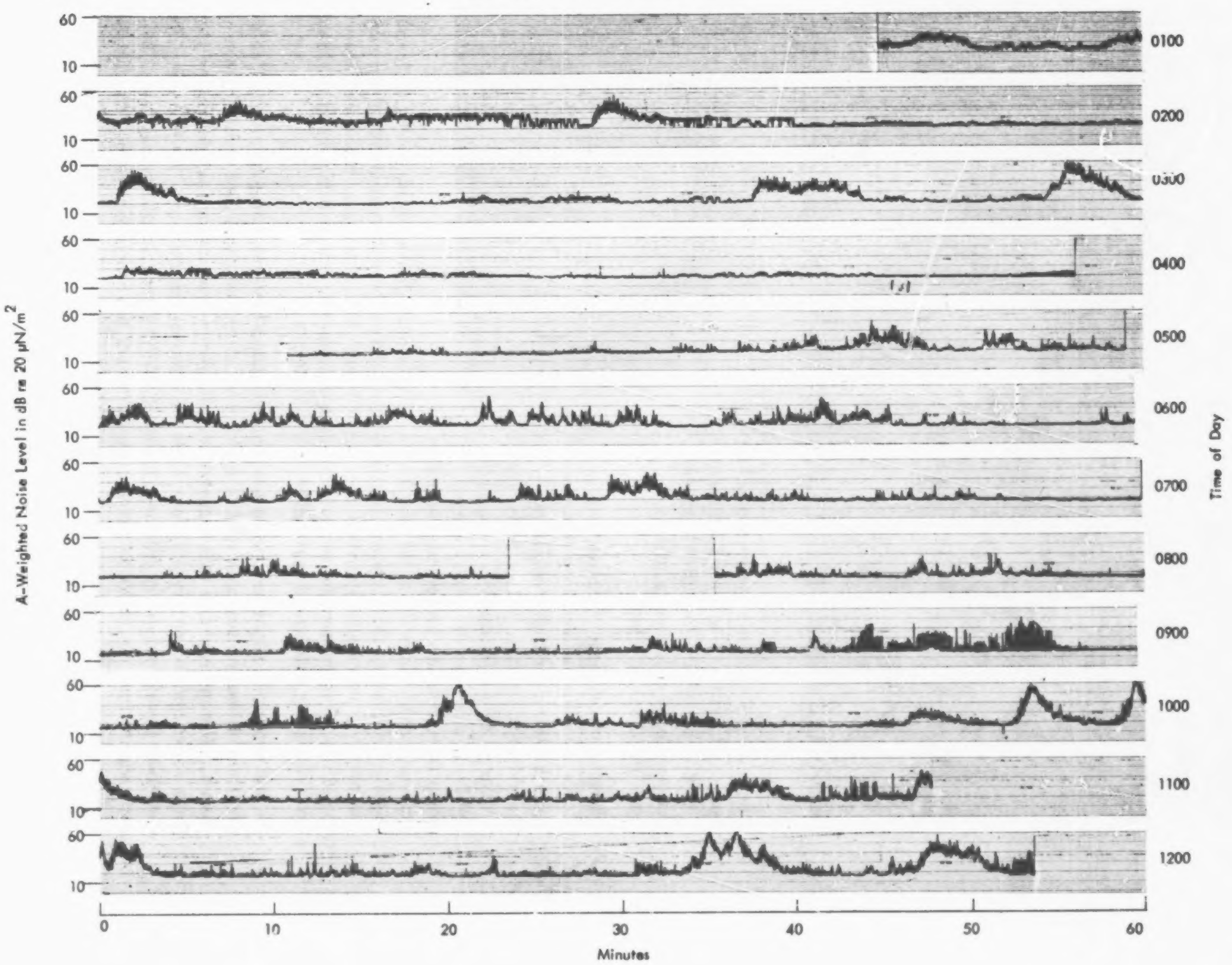
Noise Environment: Extremely quiet. Major intruding noises were generated by propeller overflights and small animals and insects. Crow calls from a quarter of a mile away were clearly audible, and feather aerodynamic noise from birds no larger than sparrows was noticeable from 30 to 40 feet away. The sounds of the rapids in the Colorado River, 3000 feet below, were clearly audible when the observer stood at the edge of the canyon, considerably attenuated 5 to 10 feet from the edge, and completely inaudible 40 feet from the edge. The canyon seems to act as a highly directional horn radiating this sound vertically.

In this location, nighttime noise greatly exceeded daytime noise because of crickets. Daytime animal noises consisted of barking by chipmunks and bird noises mentioned above. The microphone was located in a sheltered area a few feet downwind from some rocks approximately 150 feet from the edge of the canyon. At this location, the noise level frequently fell below the 16 dB(A) threshold of the measurement instrumentation. In order to make a measurement of the correct level, the sensitivity of an auxiliary sound level meter was set to a maximum level, extending the measurement range to about 11 dB(A).

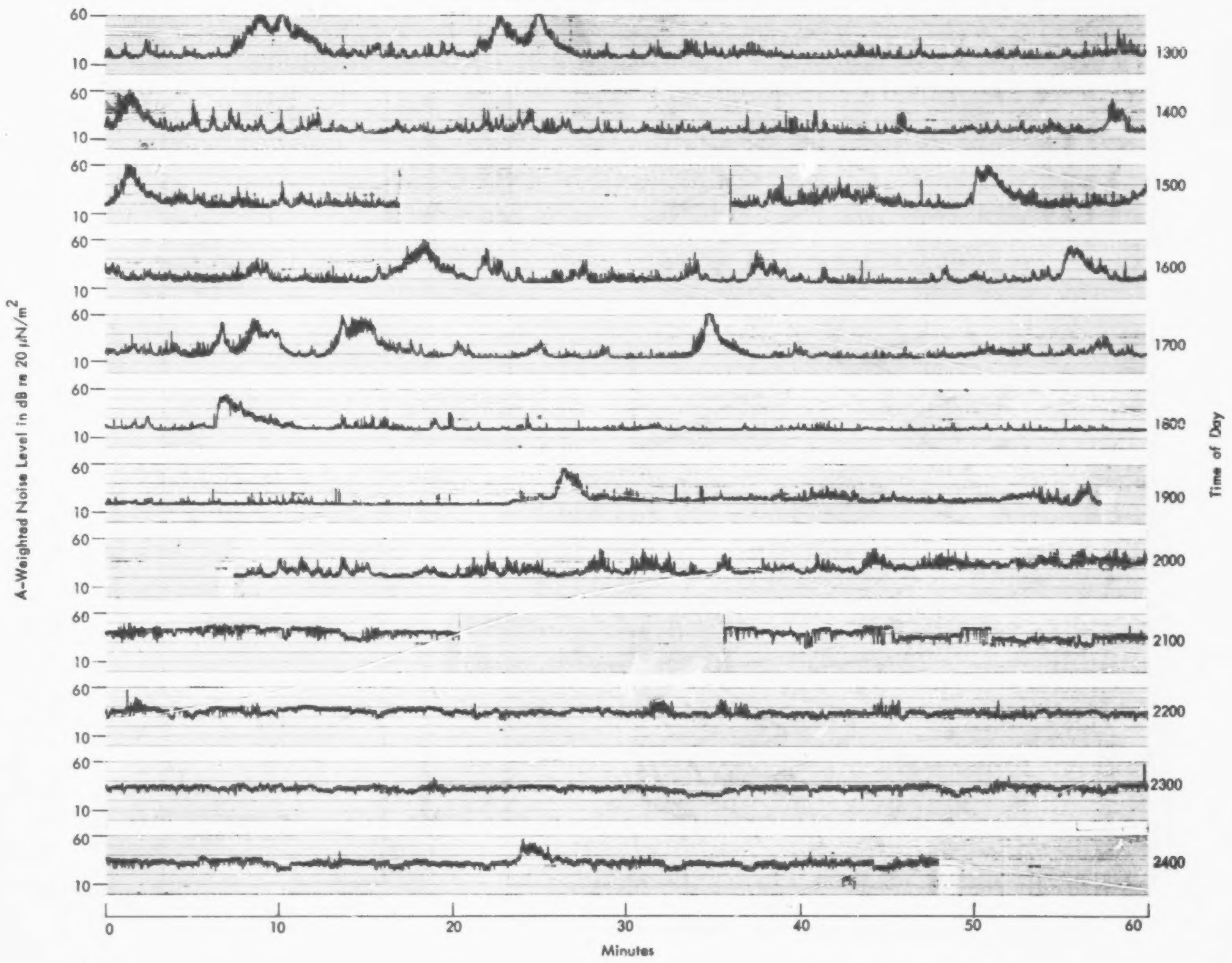
Figure A-18a. Location R – Grand Canyon, North Rim – Arizona

Figure A-18b. Time History

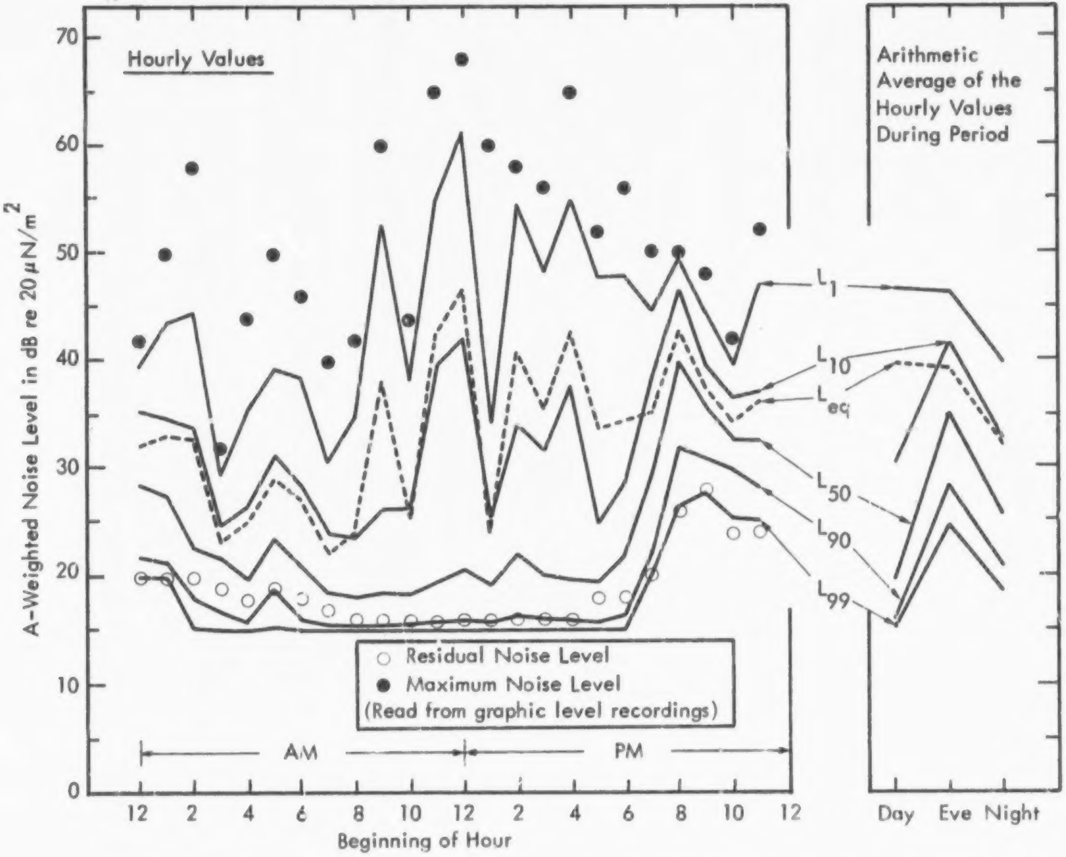
LOCATION R – 0000 Hours to 1200 Hours



LOCATION R – 1200 Hours to 2400 Hours



a) Various Measures of the Outdoor Noise Level



b) Histograms of the Percentage of Time Noise Was in Each 5 dB Interval for Three Time Periods

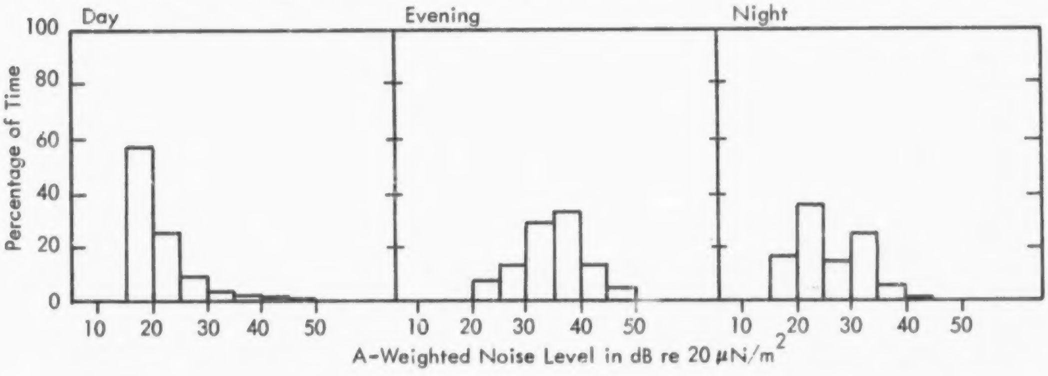


Figure A-18c. Summary of the 24-Hour Outdoor Noise Levels at Location R – Grand Canyon, North Rim

A.2 Data Acquisition and Reduction

A.2.1 Introduction

Data acquisition and reduction for the community noise survey was performed with the three systems depicted in Figure A-19 -- Standard Field Measurement System, Figure A-20 – Low Noise Field Measurement System, and Figure A-21 – Data Reduction System. Details of the application of each system, system configuration, operating procedures and performance specifications are presented in the following paragraphs.

A.2.2 Data Acquisition Systems

A.2.2.1 Standard Field Measurement System

The Standard Field Measurement System was used on locations where the ambient level of the community noise data was higher than 30 dB(A) – 13 of the 18 survey locations. It was a fully self-contained field laboratory, used for making continuous graphic level and magnetic tape recordings of the community noise levels. All equipment in this van operated from 115 vac; therefore, the system was used only at measurement locations with accessible line power.

A.2.2.1.1 System Description

Noise data was acquired through a condenser microphone shielded by a windscreen. Microphone signals were conditioned by a preamplifier and input to a microphone amplifier for amplification and A-weighted filtering. The microphone amplifier, in turn, drove a graphic level recorder and a magnetic tape recorder. A statistical distribution analyzer was mechanically coupled to the pen driving mechanism of the graphic level recorder. Data was continuously recorded on one track of the tape recorder; appropriate operator commentary was recorded on the other track.

A.2.2.1.2 Operating Procedures

To perform a 24-hour noise survey, the equipment was first interconnected as illustrated in Figure A-19, with the exception that the output of the audio oscillator was fed to the input of the tape recorder. A series of sinusoidal signals ranging from 90 Hz to 12 KHz was then input to the tape recorder, and a frequency response calibration recorded on tape. Next, the oscillator was utilized to calibrate the statistical distribution analyzer and the graphic level recorder over the 50 dB chart range.

Following recorder calibration, the preamplifier was connected to the microphone amplifier. A B & K Type 4230 acoustic calibrator was placed on the microphone, and the sensitivities of the graphic level recorder and tape recorder were adjusted to this reference level of 93.6 dB (re $20\ \mu N/m^2$). This operation completed the pre-run calibration procedure.

Following calibration, the graphic level recorder, the tape recorder, and the statistical distribution analyzer were activated and the 24-hour measurement commenced. At the completion of each hour, the statistical distribution analyzer was stopped; the amplitude distribution readings were recorded, and the analyzer was "zeroed" and restarted. During this same period – about 10 minutes – the tape was removed from the tape recorder and a new reel of tape installed. A reference voltage, with a fixed relationship to the microphone calibration, was put on the beginning of each reel of tape.

When the community noise data rose above, or fell below, the 50 dB range of the graphic level recorder, the microphone amplifier attenuator was adjusted to accommodate the dynamic range of this data. At periodic intervals over the measurement period, the system was also calibrated with the acoustic calibrator.

A.2.2.1.3 Specification

System Measurement Range:	28 dB(A) to 130 dB(A)
System Frequency Response:	20 Hz to 10 KHz
Statistical Distribution Analyzer:	Measured elapsed time of data in 10 bands, each of 5 dB bandwidth. Elapsed time above the top band and below the bottom band was also recorded.

A.2.2.2 Low Noise Field Measurement System

This system was used for making measurements at locations where (1) 115 vac power was not available, or (2) the community noise threshold dropped below the lower limits of the Standard Field Measurement System. This system was used at five of the survey locations. The system provided magnetic tape records, but no graphic records, of the 24-hour noise history. Tapes were subsequently played back in the laboratory on the data reduction system to obtain the amplitude time histories and the statistical data.

A.2.2.2.1 System Description

Community noise data were acquired through a condenser microphone shielded by a windscreen. This microphone was attached to a preamplifier connected to a precision sound level meter. The sound level meter, in turn, drove a magnetic tape recorder through 100 feet or less of cable.

A.2.2.2.2 Operating Procedure

To perform a 24-hour noise survey, the equipment was interconnected as shown in Figure A-22. System frequency and dynamic response checks were performed in the laboratory prior to field measurements, as the nature of the survey sites did not permit taking any non-portable or bulky equipment into the field.

Pre-test calibration of the sound level meter and the tape recorder were performed with the acoustic calibrator at 93.6 dB. Following calibration, the sound level meter and the tape recorder were activated and the 24-hour measurement commenced. A microphone calibration was put on the beginning and end of each reel of tape. One tape ran for three hours; consequently, eight tape changes were required during a survey. Tape records were monitored by headphone during the noise survey.

A.2.2.2.3 System Specification

Overall Measurement Range:	16 dB(A)* to 130 dB(A)
Overall Frequency Response:	20 Hz to 10 KHz

* The 16 dB(A) floor was set by the recording system – an auxiliary sound level meter had a noise floor of 11 dB(A).

A.2.3 Data Reduction System

The data reduction system – shown in Figure A-23 – was used to obtain (1) time history and statistical analysis records of the data from the Low Noise Field Measurement System, and (2) one-third octave band analyses of data from all 18 noise survey locations.

A.2.3.1 System Description

A.2.3.1.1 Time History Records

Tape recordings from the Low Noise Field Measurement System were replayed – with the same tape recorder used in the field – into a graphic level recorder and statistical distribution analyzer. This data reduction was essentially identical to the method used for making the 24-hour noise survey with the Standard Field Measurement System. The graphic level recorder was calibrated by using the reference signal recorded on tape. The microphone amplifier was set to provide an A-weighted output signal, and the 24-hour records were all replayed into the graphic level recorder.

A.2.3.1.2 One-Third Octave Band Plots

The first step in obtaining this data was to select the specific events on the 24-hour record to be analyzed. Once this data was located on the original graphic record, a second graphic record of the data was recreated from the magnetic tape to verify that the proper data was located on tape. The portion of the taped record to be analyzed was then played into the real-time analyzer and a graphic record of the third octave spectrum obtained. To obtain one-third octave plots of data, taken with the Standard Field Measurement System, a correction from A-weighting to linear was applied to output of the spectrum analyzer.

A.2.3.2 Statistical Analysis

Data from the statistical distribution analyzer consisted of records of (1) the elapsed time that the A-weighted level of the community noise data was below the bottom of the graphic level recorder chart, (2) the elapsed time the level of the data was greater than the top of the graphic record, and (3) the elapsed time the data remained within each of ten 5 dB wide bands covering the 50 dB range of the graphic level recorder. This data was subsequently processed on a CDC 6600 computer to obtain the statistical distributions for each site.

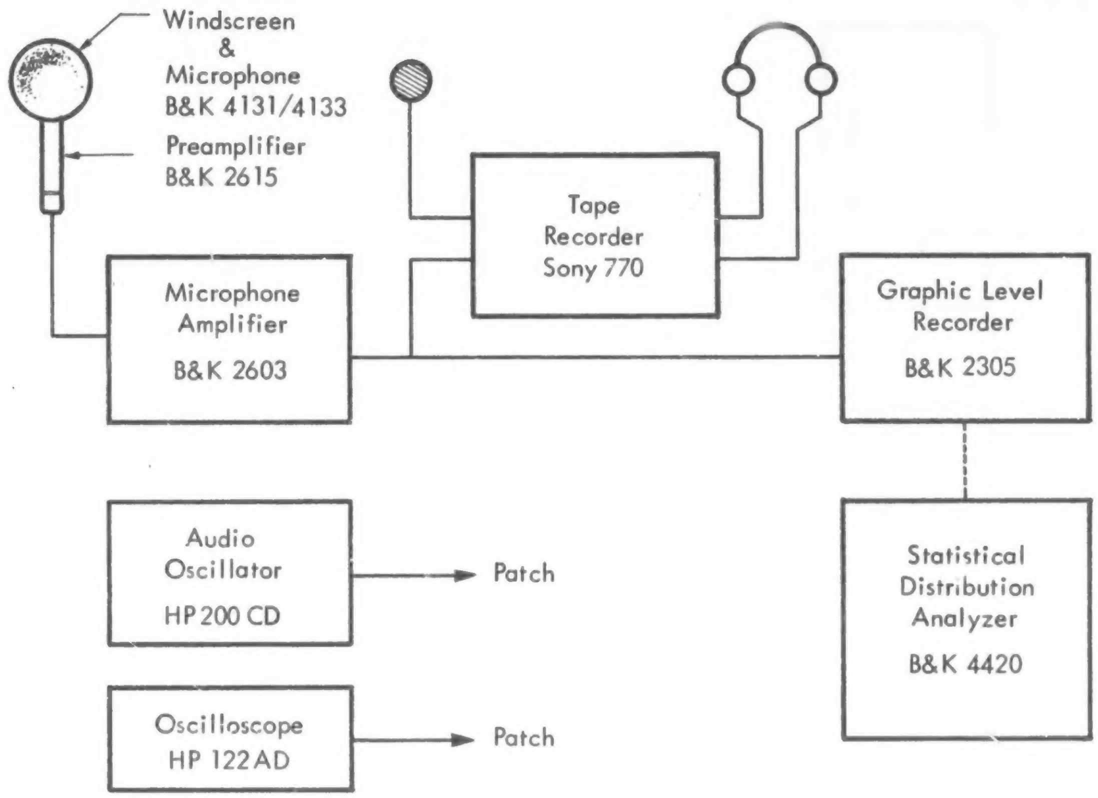

Windscreen
&
Microphone
B&K 4131/4133
Preamplifier
B&K 2615
Tape
Recorder
Sony 770
Microphone
Amplifier
B&K 2603
Graphic Level
Recorder
B&K 2305
Audio
Oscillator
HP 200 CD
Patch
Statistical
Distribution
Analyzer
B&K 4420
Oscilloscope
HP 122AD
Patch

Figure A-19. Standard Field Measurement System

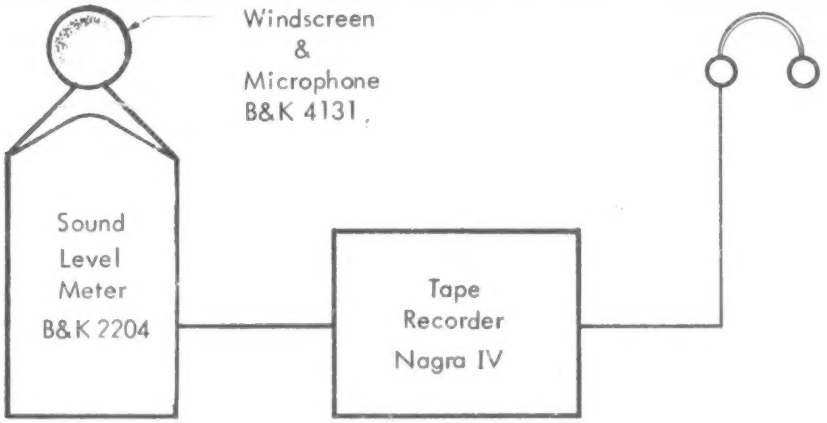

Windscreen
&
Microphone
B&K 4131
Sound
Level
Meter
B&K 2204
Tape
Recorder
Nagra IV

Figure A-20. Low Noise Field Measurement System

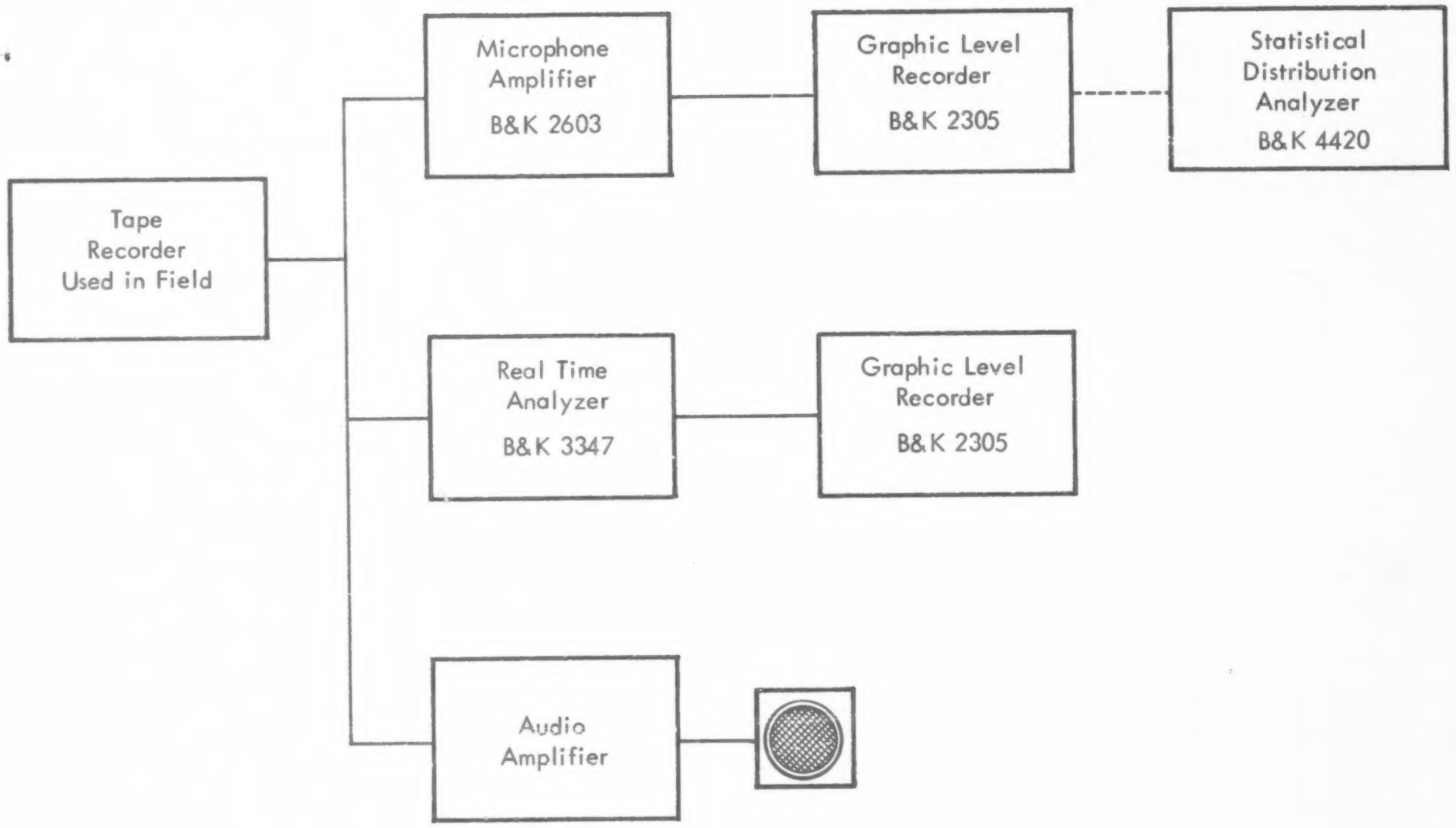

Tape
Recorder
Used in Field
Microphone
Amplifier
B&K 2603
Graphic Level
Recorder
B&K 2305
Statistical
Distribution
Analyzer
B&K 4420
Real Time
Analyzer
B&K 3347
Graphic Level
Recorder
B&K 2305
Audio
Amplifier

Figure A-21. Data Reduction System

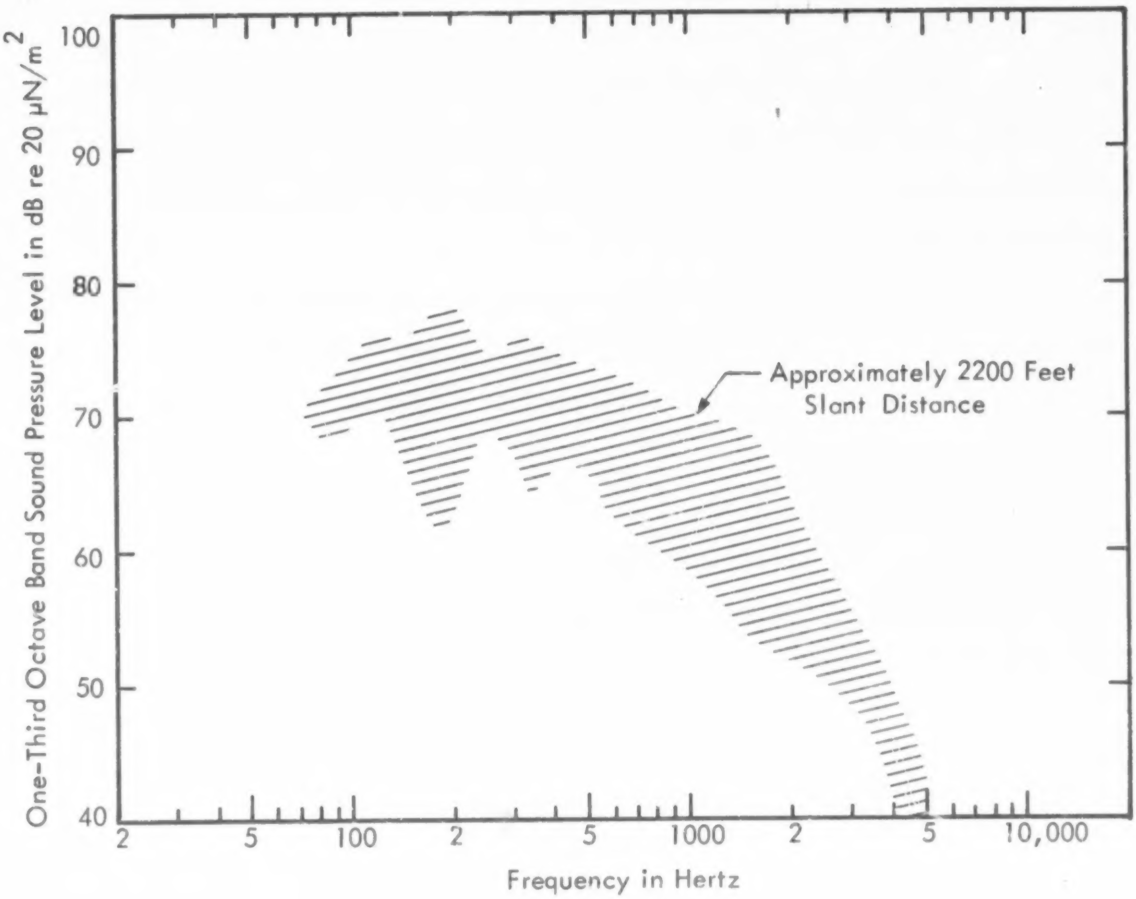


Figure B-1. Takeoff of Medium Sized Turbofan Aircraft with Power Cutback

APPENDIX B

TYPICAL NOISE SPECTRA

This appendix contains typical examples of noise spectra measured at some of the locations. The data were reduced on a real time analyzer using slow random averaging for the residual spectra and maximum for the spectra of vehicle pass-bys or other events denoted by maximum.

Measurements are at various distances from the various sources, and therefore should not be used to compare the absolute magnitude of the various sources. However, they give an indication of the relative spectral characteristics of the different sources.

Figures B-1 through B-3 are for aircraft; Figures B-4 through B-9 are for various ground transportation vehicles; Figure B-10 has some typical beach sounds; and Figures B-11 through B-13 have some sounds from nature which include crickets, birds and dogs.

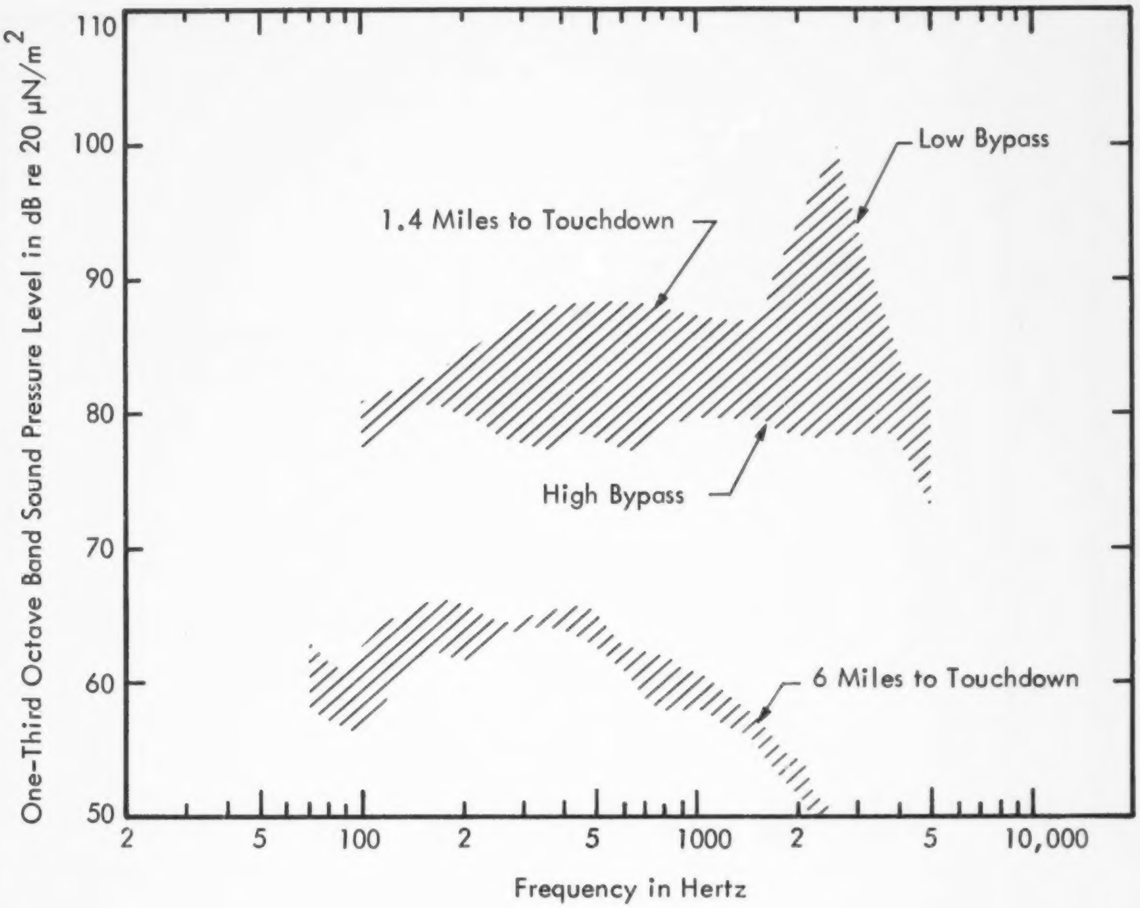


Figure B-2. Landing of Large Turbofan Aircraft

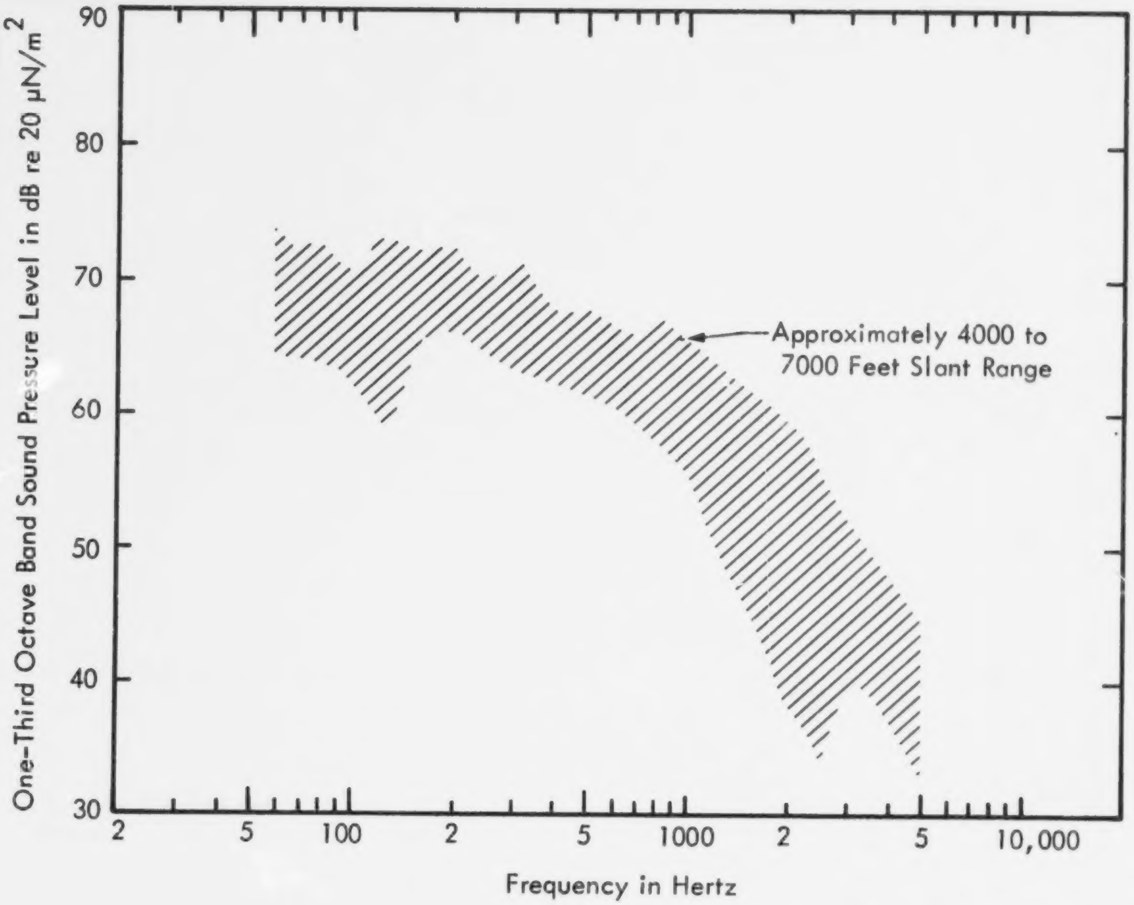


Figure B-3. Overflight of Large Turbofan Aircraft During Climbout

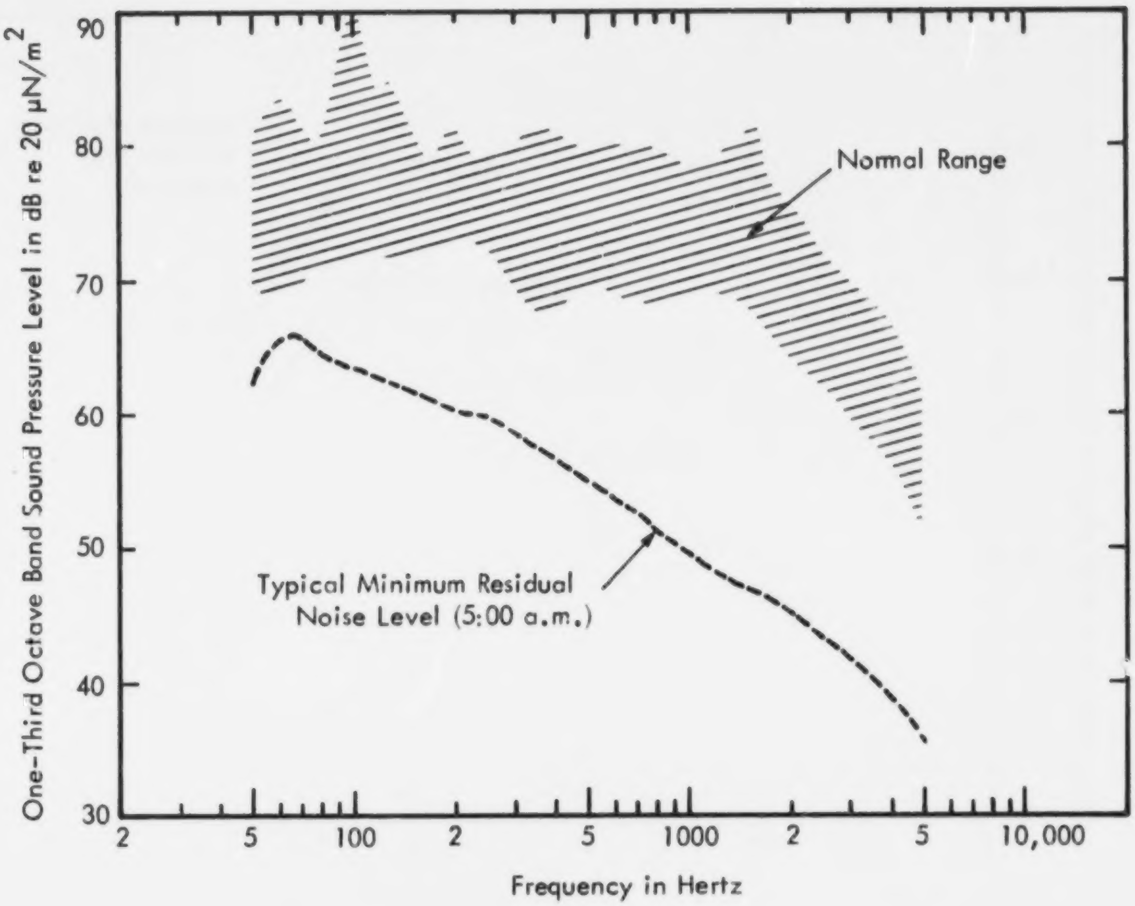


Figure B-4. Freeway, from 3rd Floor Apartment, Location A

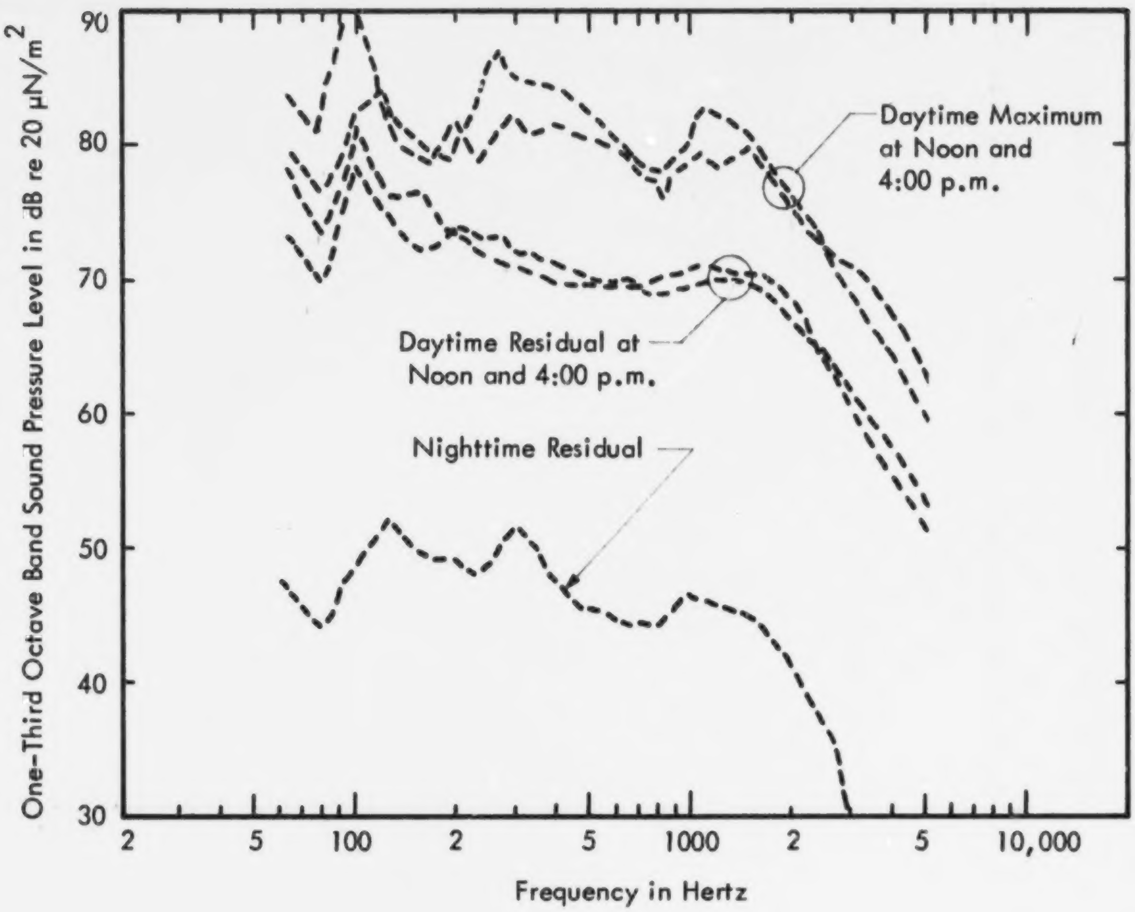


Figure B-5. Downtown City Noise, Los Angeles, Location B

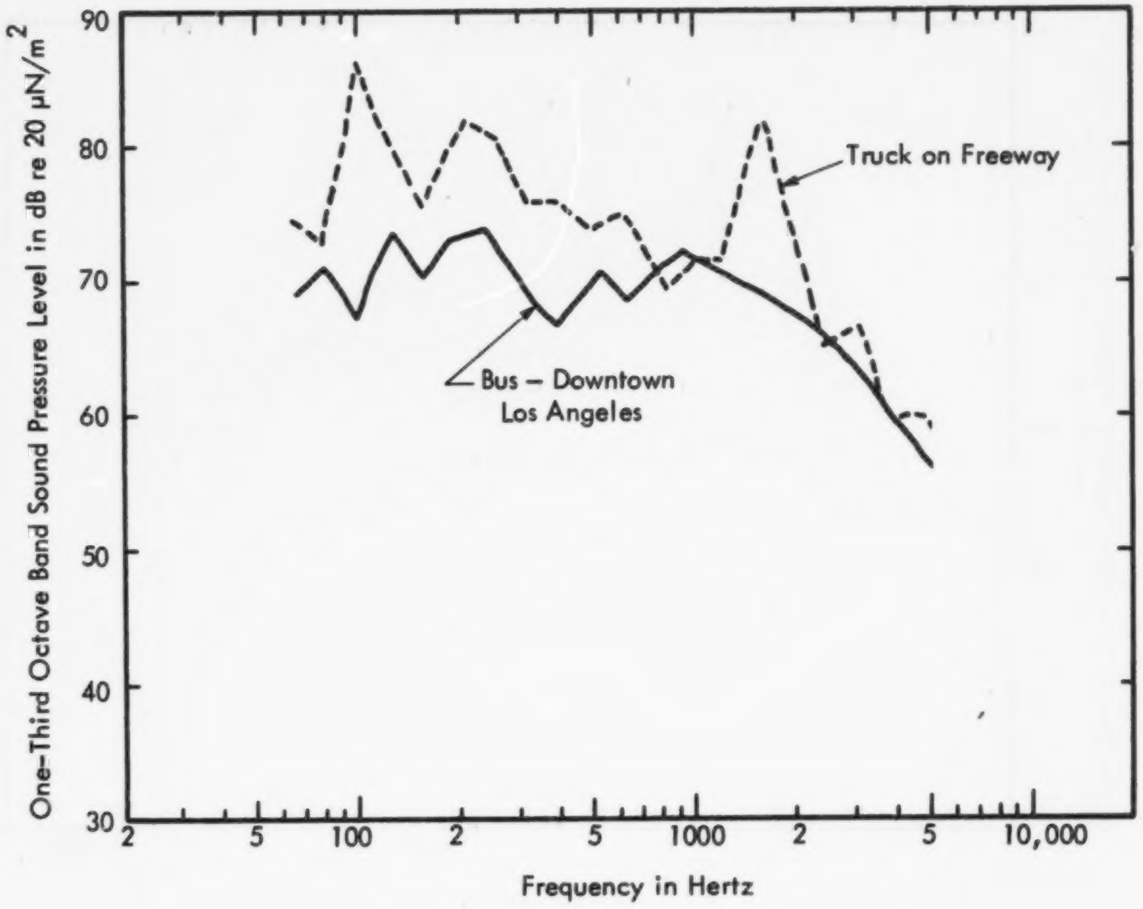


Figure B-6. Example of Maximum Noise Level of a Truck and a City Bus

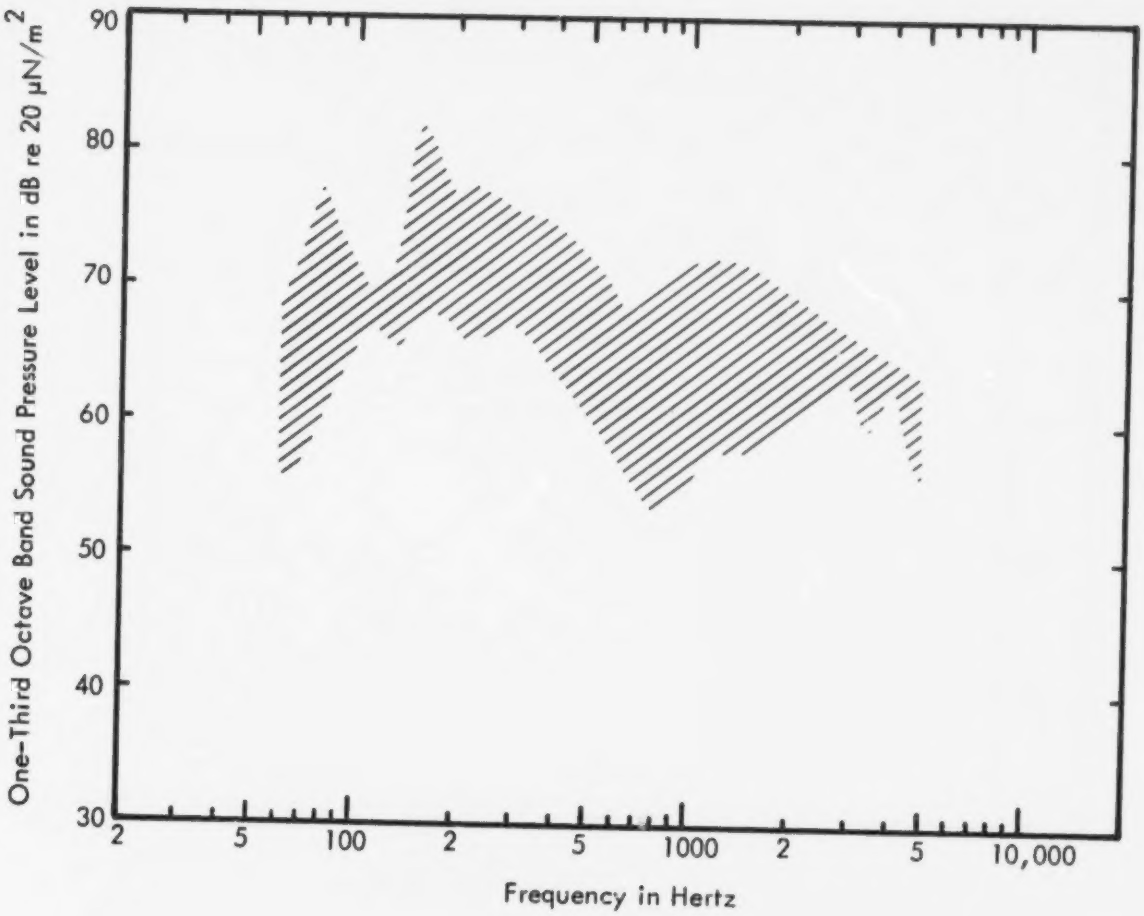


Figure B-7. Example of Maximum Noise Levels for Motorcycles

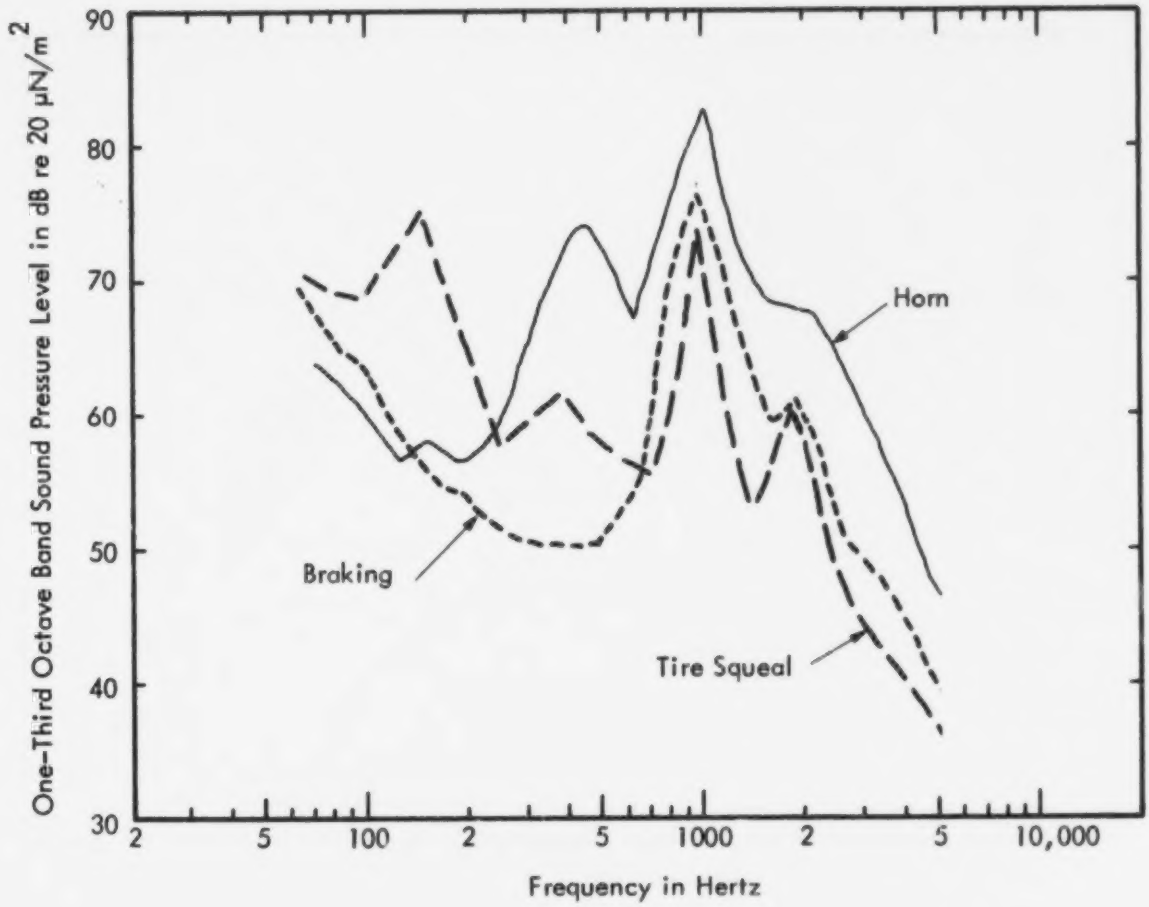


Figure B-8. Miscellaneous Automobile Noises

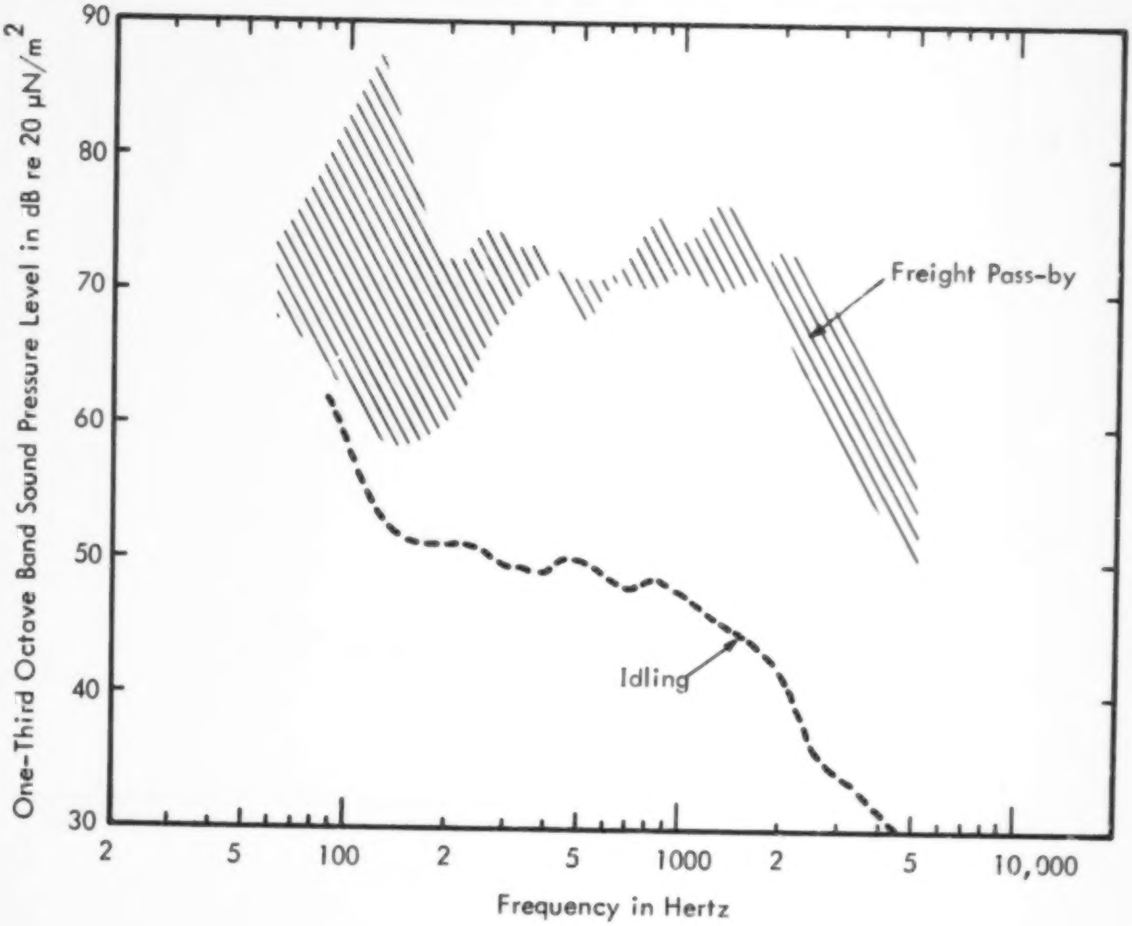


Figure B-9. Freight Train at Approximately 300 Feet

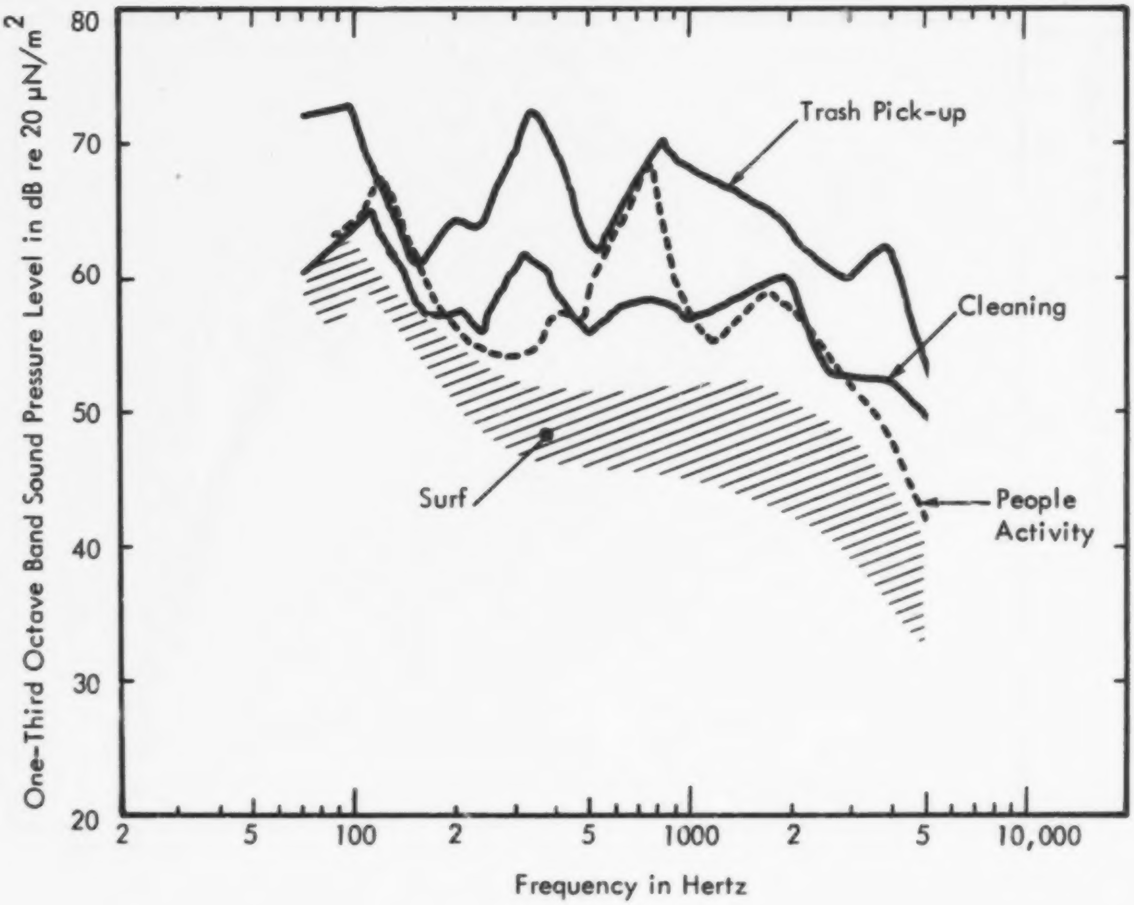


Figure B-10. Various Sounds at a Beach

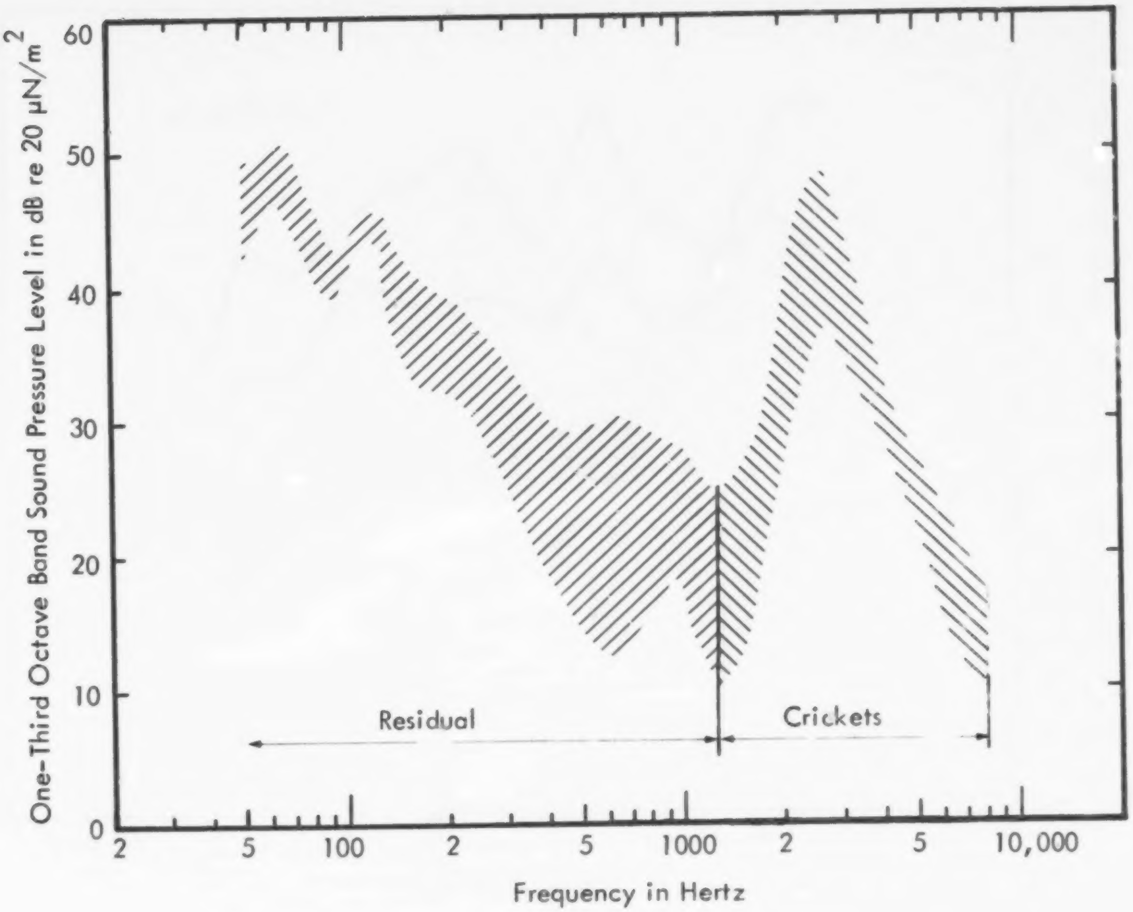


Figure B-11. Typical Examples of Crickets

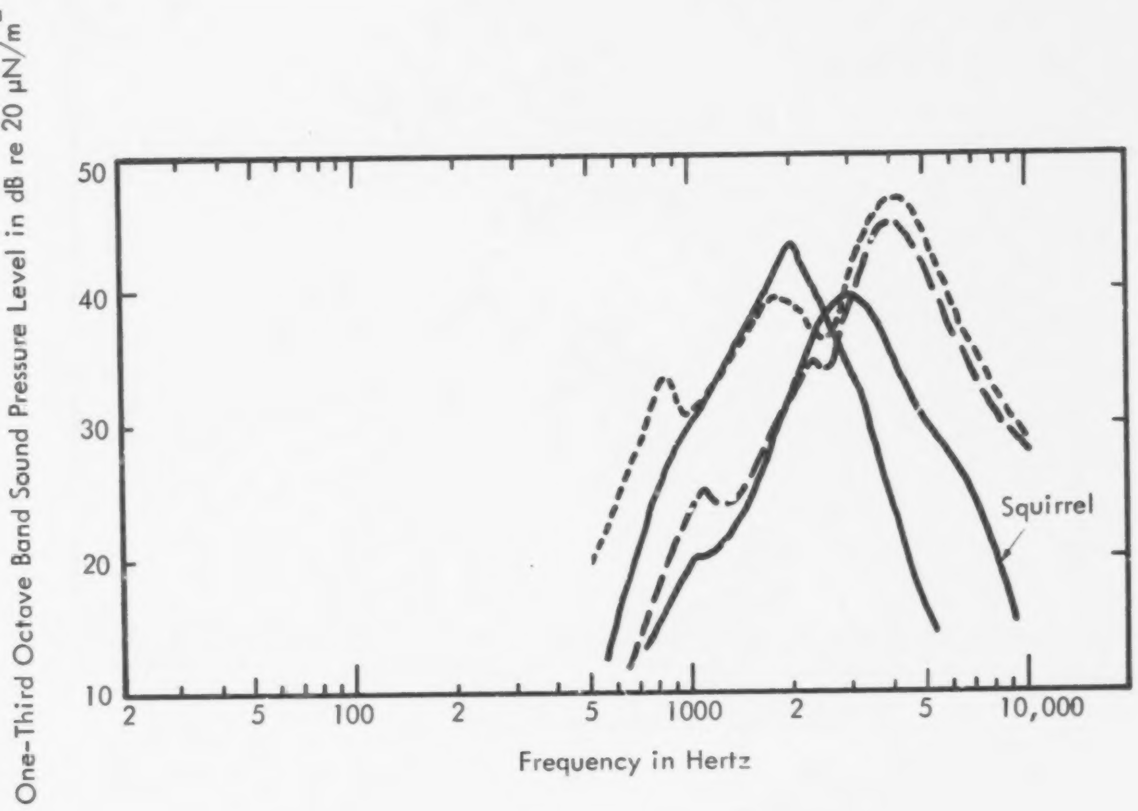


Figure B-12. Three Examples of Maximum Spectra of Birds and One of a Squirrel

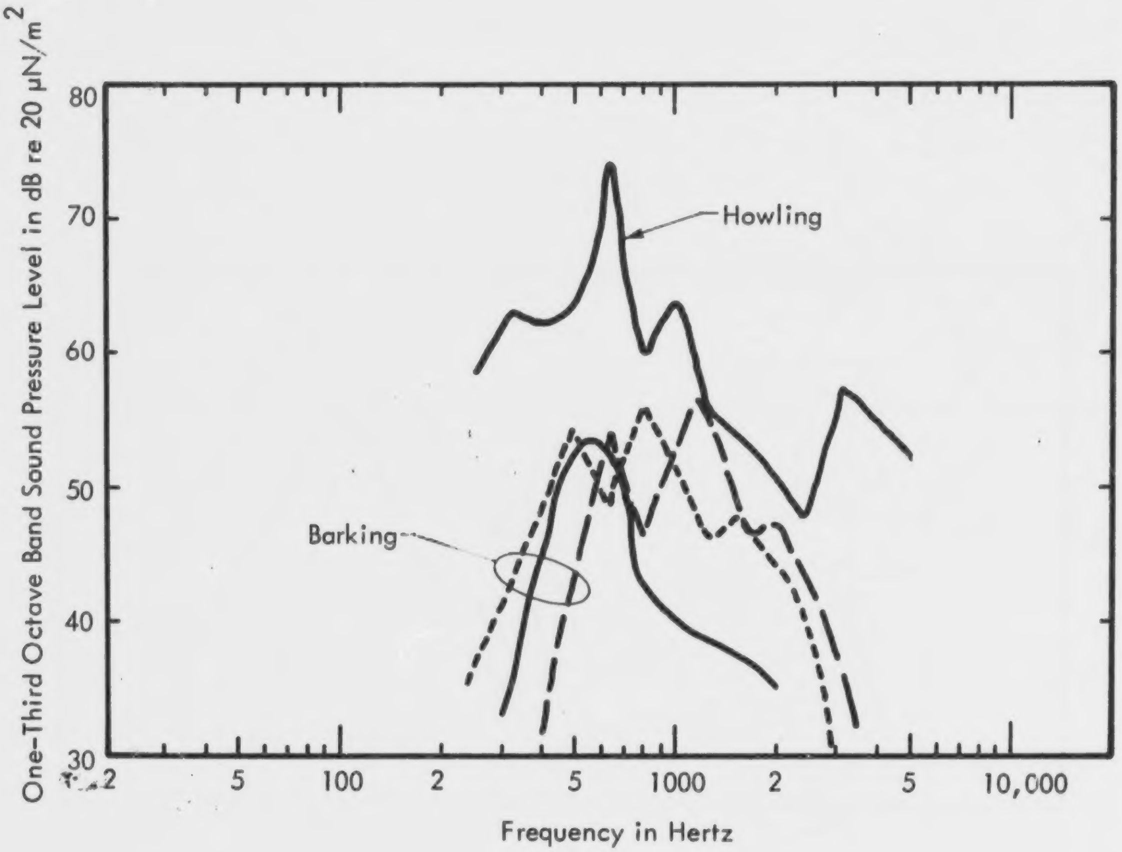


Figure B-13. Some Examples of Dogs

APPENDIX C

TERMINOLOGY

This Appendix contains descriptive definitions of some of the principal terms used in this report. For additional definitions refer to American Standard Acoustical Terminology, S1.1-1960, Revision of Z24.1-1951 and including Z24.1a, American Standards Association, May 26, 1960.

SOUND PRESSURE

The sound pressure at a point is the total instantaneous pressure at that point in the presence of a sound wave minus the static pressure at that point.

LEVEL

In acoustics, the level of a quantity is the logarithm of the ratio of that quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the kind of level must be specified.

Note 1: Examples of kinds of levels in common use are electric power level, sound-pressure-squared level, voltage-squared level.

Note 2: The level as here defined is measured in units of the logarithm of a reference ratio that is equal to the base of logarithms.

Note 3: In symbols,

$$L = \log_r (q/q_0)$$

where

L = level of kind determined by the kind of quantity under consideration, measured in units of $\log_r r$
r = base of logarithms and the reference ratio
q = the quantity under consideration
q_0 = reference quantity of the same kind

Note 4: Differences in the levels of two like quantities q_1 and q_2 are described by the same formula because, by the rules of logarithms, the reference quantity is automatically divided out:

$$\log_r (q_1/q_0) - \log_r (q_2/q_0) = \log_r (q_1/q_2)$$

DECIBEL

The decibel is one tenth of a bel. Thus, the decibel is a unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power.

Note 1: Examples of quantities that qualify are power (any form), sound pressure squared, particle velocity squared, sound intensity, sound-energy density, voltage squared. Thus the decibel is a unit of sound-pressure-squared level; it is common practice, however, to shorten this to sound pressure level because ordinarily no ambiguity results from so doing.

Note 2: The logarithm to the base the tenth root of 10 is the same as ten times the logarithm to the base 10: e.g., for a number X^2, $\log_{10^{1/10}} X^2 = 10 \log_{10} X^2 = 20 \log_{10} X$. This last relationship is the one ordinarily used to simplify the language in definitions of sound pressure level, etc.

SOUND PRESSURE LEVEL

The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure. The reference pressure is 20 micronewtons per square meter.

ONE-THIRD OCTAVE BAND SOUND PRESSURE LEVEL

The one-third octave band sound pressure level of a sound for a specified frequency band is the sound pressure level for the sound contained within the restricted band.

SOUND LEVEL (NOISE LEVEL)

Weighted sound pressure level measured by the use of a metering characteristic and weighting A, B, or C, as specified in this standard. The weighting employed must be indicated, otherwise the A-weighting is understood. The reference pressure is 20 micronewtons per square meter (2×10^{-4} microbar). Unit: decibel (dB). In this report sound level (noise level) is always A-weighted.

STATISTICAL LEVELS

Any of the statistical noise levels is given in terms of the value of the noise level which is exceeded for a stated percentage of the time period during which the measurement was made. The symbol for the noise level which is exceeded y percent of the time is L_y.

The most common measures utilized in this report are L_{99}, L_{90}, L_{50}, L_{10} and L_1, which denote the value of the noise level which is exceeded 99, 90, 50, 10, and 1 percent of the time respectively.

ENERGY EQUIVALENT NOISE LEVEL

The energy equivalent noise level for a stated period is the level of a constant, or steady state, noise which has an amount of acoustic energy equivalent to that contained in the measured noise. The symbol for the energy equivalent noise level is L_{eq}. Its mathematical definition is

$$L_{eq} = 10 \log_{10} \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} 10^{\frac{NL}{10}} dt \right]$$

where NL is the measured noise level as a function of time and t_1 and t_2 denote the times at the beginning and ending of the measurement period.

RESIDUAL NOISE LEVEL

The residual noise level is the level of the all encompassing unidentifiable noise which remain after all identifiable noises have been eliminated. For this report L_{90} has been used as an estimate of the residual noise level when no steady state identifiable noises were known to be present.

NOISE EXPOSURE AND NOISE LEVEL SCALES

"Noise exposure is the integrated effect, over a given period of time, of a number of different events of equal or different noise levels and durations." The integration may include weighting factors for the number of events during certain time periods in which people are more annoyed by noise (e.g., sleep interference by noise at night).

The various scales for noise expsoure or noise level in use throughout the world differ according to the particular method of integration or summation, time period weighting factors, or frequency weightings.

The following summarizes the essential features of and correlation between three noise scales currently used in the United States for noise exposure from aircraft noise. The correlations are necessarily approximate, but are considered valid for interrelating evaluations of aircraft noise exposure at major airports served by current commercial jet aircraft. The definitions used herein are not always the same as those formally given in the source references. In all cases, however, the simplified form given here is an exact equivalent or valid approximation thereto.

Noise Exposure Forecast (NEF)

A method currently in wide use for making noise exposure forecasts utilizes a perceived noise level scale with additional corrections for the presence of pure tones. Two time periods are used to weight the number of flights (Galloway, W.J. and Bishop, D.E., "Noise Exposure Forecasts: Evolution, Evaluation, Extensions and Land Use Interpretations," FAA-NO-70-9, August 1970).

The single event noise level is defined in terms of effective perceived noise level (EPNL) which can be specified approximately by:

$$\mathrm{EPNL} \doteq \mathrm{PNL}_{max} + 10 \log \frac{t_{10}}{20} + F, \ \mathrm{EPNdB}$$

where

PNL_{max} = maximum perceived noise level during flyover, in PNdB,

t_{10} = 10 dB down duration of the perceived noise level time history, in seconds,

and F = pure tone correction. Typically, $F \simeq +3$ dB

Community noise exposure is specified by the quantity, noise exposure forecast (NEF). For a given runway and one or two dominant aircraft types, the total NEF for both daytime and nighttime operations can be expressed approximately as:

$$\mathrm{NEF} = \overline{\mathrm{EPNL}} + 10 \log N_f - 88.0$$

where

$\overline{\mathrm{EPNL}}$ = energy mean value of EPNL for each single event at the point in question

$N_f = (N_d' + 16.7\, N_n)$ or

$= (15\,\bar{n}_d' + 150\,\bar{n}_n)$

$N_d', \bar{n}_d$ = total number and average number per hour, respectively, of flights during the day period 0700 to 2200.

$N_n, \bar{n}_n$ = the total number and average number per hour, respectively, of flights during the night period 2200 to 0700.

The constant (-88.0) dB includes an arbitrary -75 scale-changing constant and a reference number of daytime flights of 20. The constant 16.7 accounts for the 10-to-1 weighting factor for flights during the 9-hour night period.

Composite Noise Rating Method (CNR)

The original method for evaluating land use around civil airports is the composite noise rating (CNR). It is still in wide use by the Federal Aviation Administration and the Department of Defense for evaluating land use around airfields (Civil Engineering Planning and Programming, "Land Use Planning with Respect to Aircraft Noise," AFM 86-5, TM 5-365, NAVDOCKS P-98, October 1, 1964). This noise exposure scale may be expressed as follows:

The single event noise level is expressed (without a duration or tone correction) as simply the maximum perceived noise level (PNL_{max}) in PNdB.

The noise exposure in a community is specified in terms of the composite noise rating (CNR), which can be expressed approximately as follows:

$$CNR = \overline{PNL}_{max} + 10 \log N_f - 12$$

where

$\overline{PNL}_{max}$ = approximate energy mean maximum perceived noise level (PNL) at a given point

N_f = same as defined for NEF. The actual method for accounting for the number of flights and time periods uses discrete interval correction factors. These have been approximated by the use of the equivalent continuous weighted number of flights, N_f.

Community Noise Equivalent Level (CNEL)

The following simplified expressions are derived from the exact definitions in the report, "Supporting Information for the Adopted Noise Regulations for California Airports." They can be used to estimate values of CNEL where one type of aircraft and one flight path dominate the noise exposure level.

Single event noise is specified by the single event noise exposure level (SENEL) in dB and can be closely approximated by:

$$SENEL = NL_{max} + 10 \log_{10} t_{ea}, \text{ dB}$$

where

NL_{max} = maximum noise level as observed on the A scale of a standard sound level meter

and

t_{ea} = effective time duration of the noise level (on A scale) in seconds

The effective duration is equal to the "energy" of the integrated noise level (NL), divided by the maximum noise level, NL_{max}, when both are expressed in terms of antilogs. It is approximately 1/2 of the 10 dB down duration, which is the duration for which the noise level is within 10 dB of NL_{max}.

A measure of the average integrated noise level over one hour is also utilized in the proposed standard. This is the hourly noise level (in dB), defined as:

$$HNL = \overline{SENEL} + 10 \log n - 35.6, \text{ dB}$$

where

$\overline{SENEL}$ = energy mean value of SENEL for each single event,

and

n = number of flights per hour

The total noise exposure for a day is specified by the community noise equivalent level (CNEL) in dB, and may be expressed as:

$$CNEL = \overline{SENEL} + 10 \log N_c - 49.4, \text{ dB}$$

where

$N_c = (N_d + 3N_e + 10N_n)$

or $= (12\bar{n}_d + 9\bar{n}_e + 90\bar{n}_n)$

$N_d, \bar{n}_d$ = total number and average number per hour, respectively, of flights during the period 0700 to 1900

$N_e, \bar{n}_e$ = total number and average number per hour, respectively, of flights during the period 1900 to 2200

and

$N_n, \bar{n}_n$ = total number and average number per hour, respectively, of flights during the period 2200 to 0700

An alternative form of Community Noise Equivalent Level ($CNEL_2$) used in Section 5.1 employed the time period weighting factor from the Noise Exposure Forecast method. It is approximated as:

$$CNEL_2 = \overline{SENEL} + 10 \log N_f - 49.4 \text{ dB}$$

where N_f was given previously for NEF calucation.

COMPARISON OF COMPOSITE RATING SCALES FOR SPECIFYING COMMUNITY NOISE EXPOSURE

The basic expressions defined above for specifying community noise exposure are summarized below.

Noise Exposure Forecast	$\mathrm{NEF} = \overline{\mathrm{EPNL}} + 10 \log N_f - 88$, dB
Composite Noise Rating	$\mathrm{CNR} = \overline{\mathrm{PNL}}_{max} + 10 \log N_f - 12$, dB
Community Noise Equivalent Level	$\mathrm{CNEL} = \overline{\mathrm{SENEL}} + 10 \log N_c - 49.4$, dB
and	$\mathrm{CNEL}_2 = \overline{\mathrm{SENEL}} + 10 \log N_f - 49.4$, dB

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